Biological & Medical Serials

September 1918. Chemical Series. Vol. V, No. 3.

Memoirs of the Department of Agriculture in India

STORAGE

EXPERIMENTS ON THE IMPROVEMENT OF THE DATE PALM SUGAR INDUSTRY IN BENGAL

BY

HAROLD E. ANNETT, B.Sc. (Lond.), F.I.C., etc
Agricultural Chemist to the Government of Bengal

GOSTA BEHARI PAL, M.Sc. (Calcutta)

AND

INDU BHUSHAN CHATTERJEE, L.Ag. (Nagpur)
Assistants to the Agricultural Chemist to the Government of Bengal

LIBRARY
MAR 4 - 1958

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR
THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY
THACKER, SPINK & CO., CALCUTTA
W. THACKER & CO., 2, CREED LANE, LONDON

Price, Re. 1-0 or 1s. 6d.

Digitized by the Internet Archive
in 2008 with funding from
Microsoft Corporation

EDITED BY

The Council of the Pusa Agricultural Research Institute.

http://www.archive.org/details/n3memoirschemica05impeuoft

September 1918. CHEMICAL SERIES. VOL. V, NO. 3.

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA

EXPERIMENTS ON THE IMPROVEMENT OF THE DATE PALM SUGAR INDUSTRY IN BENGAL

BY

HAROLD E. ANNETT, B.Sc. (Lond.), F.I.C., etc

Agricultural Chemist to the Government of Bengal

GOSTA BEHARI PAL, M.Sc. (Calcutta)

AND

INDU BHUSHAN CHATTERJEE, L.Ag. (Nagpur)

Assistants to the Agricultural Chemist to the Government of Bengal

AGRICULTURAL RESEARCH INSTITUTE, PUSA

PRINTED AND PUBLISHED FOR

THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA

BY

THACKER, SPINK & CO., CALCUTTA

W. THACKER & CO., 2, CREED LANE, LONDON

Agents for the Sale of Government Publications.

IN THE UNITED KINGDOM.

Constable & Co., 10, Orange Street, Leicester Square, London, W.C.
Kegan Paul, Trench Trübner & Co., 68-74, Carter Lane, E.C., and 25, Museum Street, London, W.C.
Bernard Quaritch, 11, Grafton Street, New Bond Street, London, W.
P. S. King & Sons, 2 and 4, Great Smith Street, Westminster, London, S.W.
H. S. King & Co., 65, Cornhill, E.C., and 9, Pall Mall, London, W.
Grindlay & Co., 54, Parliament Street, London, S.W.
T. Fisher Unwin, Ld., 1, Adelphi Terrace, London, W.C.
W. Thacker & Co., 2, Creed Lane, London, E.C.
Luzac & Co., 46, Great Russell Street, London, W.C.
B. H. Blackwell, 50 and 51, Broad Street, Oxford.
Deighton, Bell & Co., Ld., Cambridge.
Oliver & Boyd, Tweeddale Court, Edinburgh.
E. Ponsonby, Ld., 116, Grafton Street, Dublin.

ON THE CONTINENT.

Ernest Leroux, 28, Rue Bonaparte, Paris.
Martinus Nijhoff, The Hague, Holland.

IN INDIA AND CEYLON.

Thacker, Spink & Co., Calcutta and Simla.
W. Newman & Co., Calcutta.
R. Cambray & Co., Calcutta.
S. K. Lahiri & Co., Calcutta.
B. Banerjee & Co., Calcutta.
The Indian School Supply Depôt, 309, Bow Bazar Street, Calcutta, and 226, Nawabpur, Dacca.
Butterworth & Co. (India), Limited, Calcutta.
The Weldon Library, 18-5, Chowringhee Road, Calcutta.
Rai M. C. Sircar Bahadur and Sons, 75-1-1, Harrison Road, Calcutta.
Higginbothams, Ld., Madras.
V. Kalyanarama Iyer & Co., Madras.
G. A. Natesan & Co., Madras.
S. Murthy & Co., Madras.
Thompson & Co., Madras.
Temple & Co., Madras.
P. R. Rama Iyer & Co., Madras.
Thacker & Co., Ld., Bombay.
A. J. Combridge & Co., Bombay.
D. B. Taraporevala, Sons & Co., Bombay.
Radhabai Atmaram Sagoon, Bombay.
Sunder Pandurang, Bombay.
Gopal Narayan & Co., Bombay.
Ramchandra Govind & Son, Kalbadevi, Bombay.
N. B. Mathur, Superintendent, Nazir, Kanun-i-Hind Press, Allahabad.
A. Chand & Co., Lahore, Punjab.
Rai Sahib M. Gulab Singh & Sons, Mufid-i-Am Press, Lahore.
Superintendent, American Baptist Mission Press, Rangoon.
S. C. Talukdar, Proprietor, Students and Company, Cooch Behar.
A. M. & J. Ferguson, Colombo, Ceylon.

PREFACE.

At the present time the development of Indian industries is occupying the serious attention of the authorities.

The following pages consist of an attempt to give detailed information relating to a very important industry which has managed to survive in the face of many difficulties. We have been able, as a result of our work, to make certain definite recommendations for the improvement of this industry. India produces at least 300,000 tons of sugar per year from various palms. Bengal is said to produce about 100,000 tons of this quantity. European firms in Madras purchase about 25,000 tons of raw palm sugar for refining and distilling purposes annually; so that we have an industry the annual value of whose output in normal times is roughly $2\frac{1}{2}$ million pounds sterling.

It would be difficult to find any other industry of like magnitude which has received so little investigation.

Owing to my having been placed on special duty in the United Provinces, the publication of the results of these experiments has been much delayed, and even then the results of some of the work done have had to be omitted.

It would be ungrateful of me if I did not again acknowledge the great help which Mr. E. G. Macleod, of Kotechandpur, Jessore, has continued to give us in our work.

H. E. Annett.

CONTENTS.

			Page.
Part	I.	Introduction	69
Part	II.	Tapping the trees	72
Part	III.	Work in the field	76
	A.	The improvement of the quality of the juice ...	76
	B.	Improvements in the quality of *gur*	95
	C.	Fuel Experiments	98
Part	IV.	Conclusions	116

EXPERIMENTS ON THE IMPROVEMENT OF THE DATE PALM SUGAR INDUSTRY IN BENGAL.

INVESTIGATIONS IN 1915–16.

BY

H. E. ANNETT, B.Sc. (Lond.), F.I.C., etc.,

Agricultural Chemist to the Government of Bengal,

GOSTA BEHARI PAL, M.Sc. (Cal.),

AND

INDU BHUSHAN CHATTERJEE, L. Ag. (Nag.),

Assistants to the Agricultural Chemist to the Government of Bengal.

[Received for publication on 6th December, 1917.]

PART I. INTRODUCTION.

THE importance of various palm trees in India as a source of sugar has already been pointed out by one of us in a recent memoir.[1] That memoir was a preliminary general survey of the agriculture and chemistry of the date sugar industry in Bengal. A great deal of information was collected. Some preliminary recommendations were made for the improvement of the industry. Most of the work now to be described was performed during the cold weather of 1915-16, but it has had to be done in conjunction with other work.

It will not be out of place to recapitulate here some of the advantages of the palm tree as a source of sugar.

1 Annett, H. E., Lele, G. K., and Amin, Bhailal M. "The Date Sugar Industry in Bengal: An Investigation into its Chemistry and Agriculture." *Mem. Dept. Agric., India, Chem. Ser.*, vol. II, no. 6.

The yield of sugar is certain from year to year, and is not affected by drought or floods as is the case with sugarcane. Very little cultivation expense has to be incurred. A longer sugar-making season is possible with palms than with sugarcane.

The cost of production per maund of *gur* (raw sugar) is less in the case of the date palm and palmyra palm than it is in the case of sugarcane. This is witnessed by the fact that the pre-war price of palm *gur* was Rs. 3 to Rs. 3-8 per maund (82lb.), when cane *gur* was selling at Rs. 5 to Rs. 6 in the same district. The sugar content is more or less the same in the two cases. If the colour of the palm *gur* could be improved, it would probably fetch a better price.

The juice of the palm tree, if collected under careful conditions, is very pure and contains very little sugars other than cane sugar. In Bengal, under present conditions, the juice is not collected under good conditions. The work to be described will show how, in a simple manner, these conditions can be improved.

No crushing mills are required to obtain the juice. This would save a certain amount of capital expenditure in a large factory.

It would be only fair to point out here, however, that there is one big disadvantage, in that, in the case of the sugarcane, no fuel has to be purchased, the sugarcane megass, *i.e.*, the residue after crushing the juice out of the canes, being used as the source of fuel. One has to buy fuel in the case of the palm sugar industry, though the dried leaves cut off from the trees last for a month at the beginning of the season.

Attention has been paid in the present work to the fuel question.

One of the suggestions put forward in the memoir above quoted was that a Hadi process plant, capable of dealing with 60 to 100 mds. of juice per day, might be set up in the district, and that juice be purchased from the cultivators at 4 to 4½ annas per maund. A better quality of *gur* would probably be thus obtained, and it would probably pay to put in a centrifugal plant to produce sugar from the *gur*. In accordance with this suggestion, an up-to-date maple-sugar-making plant was imported from America. By means of this we at times made 3 to 3½ mds. of *gur* per day. Such a scheme would be unworkable in practice, however, unless the owner of the plant also had his own trees. Personal experience showed us that one is entirely at the mercy of the cultivator, and no amount of argument will persuade him to sell his juice at a reasonable rate. We were only able to get juice at 7 to 8 annas per maund, and at that rate the venture could only result in heavy loss. It must be

remembered, however, that the price of *gur* was much higher this season than at the time this suggestion was made.

It will be seen that a good deal of useful information has accumulated as a result of this last season's work.

The importance of improving the native industry has been kept chiefly in mind, but the possibility of the production of palm sugar on the factory scale has not been lost sight of.

PART II. TAPPING THE TREES.

It is considered advisable to describe again the process by which the juice is obtained from the wild date palm, since otherwise various terms would need explanation in the course of the text. The following account is taken from the previous memoir written by one of us.

The usual articles required for this work consist of (1) a rope (*dara*), 9 ft. long and 1 to 1½ inches thick, which is loosely tied round the operator and the tree, and by means of which a man can climb rapidly and safely; (2) a plaited palmyra leaf bag (the *thungi*), about 1 ft. deep, in which are carried the *daws*, spouts, and other articles, and to which are attached a wooden hook and two loops of string, the loops going round the waist of the man, and being tied in front, and the hook suspending an earthen pot; (3) a piece of canvas or goatskin (the *kolach*), 1 ft. wide, which is tied on the man's back to protect him from the rubbing action of the climbing rope; and (4) three *daws* (bill-hooks), one heavy and two lighter ones. (All the above are shown in Plate III of the memoir quoted.)

The tapping is a delicate operation, commenced in October and done in several stages. With the heavy *daws*, all the old leaves are cut off below the crown, and all the leaves from one side of it, leaving only a few at the top, the bases of the petioles and the sheaths being carefully removed (*see* Plate IV of the memoir referred to above). Then, with the lighter *daws*, the outer zone of the loose soft tissue is pared off in long slices, leaving only a thin covering of it over the sap-supplying inner zone, which corresponds to the woody zone in the older wood of all palms. Very great care must be taken not to expose this inner tissue at this stage, otherwise the tree is sure to rot and die, as often happens when the operation is entrusted to inexperienced hands. The experts at this work are called *siulis* or *gachis*. After this first operation the trees are given about 8 days' rest, by which time the fine covering of soft tissue gets a little hardened and

begins to crack. The second operation consists in removing this covering, great care being taken not to cut into the inner zone which is now for the first time simply exposed. Then comes a rest of 12 to 14 days, which brings us to the beginning of November. The *gachi*, as a rule, divides his trees into six convenient groups called *palas*, each containing 50 or 60 trees, the number which he can operate on in one day, 300 to 400 being the total number which one man can manage. Next, after midday, he cuts two eye-shaped notches, 3 to 4 inches long and about ¼ inch deep at the base, their lower sides being straight and converging to a point, below which a split bamboo spout is driven into the tree. About 3 or 4 o'clock in the afternoon an earthenware pot is suspended under the spout, and the juice which trickles down is collected. The pots are removed early next morning at 6 or 7 A.M. before the sun gets on them and the juice boiled into sugar. On the following night juice is again collected generally without renewing the cut, though the surface is as a rule cleaned with the hard stem of a palm leaf. A much smaller quantity is generally obtained than on the first night. On the third evening also more juice is, as a rule, collected; but it is only small in amount and of very poor quality. Each night's juice has a distinctive name given to it. That of the first night is called *jiran* (rest), of the second night *dokat* (second cut), and of the third night *tekat* (third cut). On the fourth and fifth nights no juice is collected. After six days the cut is renewed a little, and for three days juice is again obtained, being given the same names as before. The tapping process goes on in this way throughout the season. The first 2 to 3 weeks' supply is very valuable, for the *gur* produced from it, called *Nolen-gur*, has a very pleasant smell and is much appreciated by the consumers. It fetches a high price.

Of course it is not to be supposed that in all cases such a regular system of tapping is carried out. Sometimes the trees are cut for 2 to 3 days in succession, and sometimes they may be cut every fourth day; but such frequent tapping soon destroys the trees.

The *daws* (bill-hooks) require much attention. They are daily sharpened on a piece of dry wood sprinkled over with fine sand while the *daws* are new, but with dry potter's clay afterwards. They may even require tempering once or twice in a season. The tip is especially looked to. If too sharp and pointed, it cuts into the trees and injures them, sometimes fatally, and if too blunt, it tears the tissues, whereas a clean cut must be obtained.

The following plan illustrates the daily round of work in the garden :—

Order of tapping.

Days	Divisions of the garden	Cuts
1st day	1st portion	Jiran
2nd day	1st portion	Dokat
	2nd do.	Jiran
3rd day	1st portion	Tekat
	2nd do.	Dokat
	3rd do.	Jiran
4th day	1st portion	Rest
	2nd do.	Tekat
	3rd do.	Dokat
	4th do.	Jiran
5th day	1st portion	Rest 2nd day
	2nd do.	Rest 1st „
	3rd do.	Tekat
	4th do.	Dokat
	5th do.	Jiran
6th day	1st portion	Rest 3rd day
	2nd do.	Rest 2nd „
	3rd do.	Rest 1st „
	4th do.	Tekat
	5th do.	Dokat
	6th do.	Jiran

As a rule there is no *dokat* or *tekat* juice in November. In December *dokat* juice as well as *jiran* is obtained. In January we have *jiran*, *dokat* and *tekat* juices.

Towards the end of January, and thence till the end of the season, the trees are slightly cut for *dokat* juice as well as for *jiran*. That is, they are cut on two successive nights, (1) for *jiran*, (2) for *dokat*. *Dokat* juice yielded from a surface cut afresh is called *dokat pocha*.

A fair amount of juice drops from the cut surface during the day. This is collected and is called *ola*. It is very poor in quality and is boiled into molasses which is sold for mixing with tobacco at 12 annas per maund[1] (*kutcha*). In normal cases the cut is renewed week after week until about the middle of March, by which time a very deep notch is made into the tree, reaching one-third or at times half through it. Each succeeding cut tends to go slightly higher up than the previous one. The next year's cut is made on the opposite side, but at a slightly higher level, the tree having grown in

[1] One maund (*kutcha*) = 60lb. roughly.

height in the meantime. This continued year after year gives the plant its characteristic zig-zag appearance. It is noticeable that trees are almost always tapped only on the east and west side. The first tapping generally takes place on the east side.

We have seen trees which have been tapped continuously for almost fifty years. This can be told by the number of notches. The age of a date tree, which has been tapped regularly, can thus be easily told by adding the number of notches to six years, the age at which, as a rule, tapping first takes place. The average sap-yielding life of a tree, however, is probably not much more than 25 years. Even then, the old tree is still of some considerable value as a fuel and for other purposes.

The yield of sap is greatest in midwinter. The sap collected on calm and cloudless nights gives *gur* of the best quality. Cloudy and foggy nights affect both the quality and quantity of the juice adversely. It is said that in January, when the trees are in full inflorescence, the sap becomes very poor in sugar, though profuse in quantity, and as a rule does not produce good crystals.

Smoking the pots. The earthen pots in which the juice is collected are well smoked every morning as soon as they are emptied. It is noticeable that after smoking the pots are always kept mouth downwards on the ground all day, until they are hung up on the trees again in the afternoon. The smoking is done by putting a number of pots mouth downwards over a heap of rubbish, such as leaves, date leaves or *bhusa* (finely broken straw), and then firing the rubbish. The interior of the pots is thus thoroughly smoked. The treatment is over in a few minutes, and is supposed to help to keep the juice from fermentation.

PART III. WORK IN THE FIELD.

The work will be dealt with under the following heads :—

A. The improvement of the quality of the juice.
   (*a*) Night juice.
   (*b*) Day or *ola* juice.
   (*c*) The effect of washing the cut surface of the tree on the quality of the juice.

B. Improvements in the quality of the *gur*.
   (*a*) Colour.
   (*b*) Sugar content.

C. Fuel experiments.

A. THE IMPROVEMENT OF THE QUALITY OF THE JUICE.

(*a*) Night Juice.

In our previous work it was shown that much sugar was lost by inversion during the night after the juice had left the tree. We suggested that this loss might be partly due to the dirty condition of the earthen pots which are used to collect the juice. We therefore considered that, if metal receptacles were used as a means of collection, a better quality of juice would be obtained. Preliminary experiments had also indicated to us in our former work that, if small amounts of formalin were placed in the collecting pots over-night, the juice would be better preserved.

In Madras the Excise authorities enforce the use of lime cream in pots which are being used to collect juice from the palms for sugar-making. A personal study of the conditions under which this industry is carried on showed that the quality of the juice obtained, and of the jaggery made from it, was of far higher quality than the juice and *gur* in Bengal.

In our previous work we also investigated the effect which the common Bengal practice of smoking the pots has on preserving the juice. The effect was found to be distinctly beneficial. It may be mentioned that it is also a fairly common practice to smoke pots in which milk is to be transported. The reason for this preservative effect of the smoke will be discussed elsewhere.

The following series of experiments were planned to compare the five different means of collecting the juice set out below :—

I. Earthenware pots such as the tappers themselves use, but these pots were not smoked or treated in any way.

II. Earthenware pots such as the tappers use, but the pots were smoked nightly ; hence this is exactly the way in which the juice is collected in the date sugar districts.

III. Earthenware pots such as the tappers use, but the inside was daily lightly smeared with lime made up by mixing lime and water to a thick cream.

IV. Earthenware pots containing a small amount of formalin, 50 c.c. of ordinary commercial formalin, *i.e.*, 40 per cent. was diluted to 1000 c.c. Five c.c. of this weak solution was put into each pot. (28 c.c. = 1 oz. roughly.)

V. Metal buckets.[1] The buckets used were buckets such as are used in North America for the collection of maple juice, and were obtained from Messrs. Grimm and Co., Vermont. These buckets received no treatment beyond daily washing with water.

Each of the above five series consisted of 8 pots, or in the case of No. V of 8 buckets. Thus there were 40 trees under experiment nightly. Efforts were made to use only trees yielding *jiran* juice.

The pots were attached to the tree in the afternoon in the usual manner and removed next morning at 7 to 8 A.M. Since it was impossible with the staff available to analyse the juice from the 40 individual receptacles each day, the juice of each series was mixed together, and from the five samples thus obtained samples were drawn for analysis. The sucrose and reducing sugar were then determined in each sample.

The experiment was continued almost daily for more than three weeks, so that fairly reliable results were obtained. It should be mentioned that in the first place all the pots used were quite new on the first day of experiment. The four series of earthen pots were plainly marked with distinctive colours, and the pots of each series were used only for their own particular series throughout the experiment.

The only criticism which can be offered of the method of experiment seems to be the fact that we were not dealing with trees all of which gave juice of the same quality.

[1] Investigations at Vermont, U. S. A., show that sap keeps better in metal vessels in U. S. A. (*Jour. Soc. of Chem. Ind.*, May 30th, 1914.)

It would, however, be impossible to select trees of such a uniform character. By including 8 trees nightly in each series, and carrying out the experiments through more than three weeks, as above described, it was hoped that any difference factor due to original difference in composition of the juice of each series would be largely eliminated. The results obtained are so definite that we can readily trace the action of each particular treatment. With a view to finding the kind of difference likely to be due to difference among the trees, on two nights experiments were carried out with series of pots all of which had been untreated. On the 7th February 1916, and 14th February, 1916, five sets of pots, eight in each set but all untreated, were used for juice collection. The results obtained are set out in the table under the dates mentioned. It will be seen that there is considerable variation among the trees themselves, but the ratio of reducing sugars to total sugars shows the juices to be all very bad.

Perhaps a more reliable way of testing the various methods of juice collection is that set out on pages 81 and 82.

All the results obtained in the series of experiments above described are set out in the tables below:—

Date	Method of collection	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar	Remarks
20-1-16	Untreated pots ..	9·98	..	..	..	
	Do. ..	12·34	0·51	12·85	4·0	
	Do. ..	11·57	1·22	12·79	9·5	
21-1-16	Untreated pots ..	10·10	1·16	11·26	10·3	
	Smoked ,, ..	11·59	0·74	12·33	6·0	
	Limed ,, ..	10·02	0·87	10·89	8·0	
	Formalin ,, ..	10·54	0·95	11·49	8·3	
	Metal buckets ..	10·95	1·64	12·59	13·2	
22-1-16	Untreated pots ..	..	..	..	..	Too badly fermented to analyse.
	Smoked pots ..	12·10	0·94	13·04	7·2	
	Limed ,, ..	11·61	0·91	12·52	7·3	
	Formalin ,, ..	9·15	2·60	11·75	22·1	
	Metal buckets ..	8·94	2·60	11·54	22·5	
23-1-16	Untreated pots ..	..	4·00	..	..	Too badly fermented to analyse.
	Smoked pots ..	10·14	1·25	11·35	11·0	
	Limed ,, ..	10·02	1·88	11·90	15·8	
	Formalin ,, ..	9·93	2·08	12·01	17·3	
	Metal buckets ..	8·63	2·56	11·19	22·9	

Date	Method of collection	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar	Remarks
24–1–16	Untreated pots ..	8·21	1·33	9·54	14·0	
	Smoked ,, ..	10·31	0·85	11·16	7·6	
	Limed ,, ..	9·82	0·62	10·44	5·9	
	Formalin ,, ..	10·59	1·11	11·70	9·5	
	Metal buckets ..	10·26	1·61	11·87	13·5	
25–1–16	Untreated pots ..	10·35	0·98	11·33	8·6	
	Smoked ,, ..	11·17	0·52	11·69	4·5	
	Limed ,, ..	9·89	1·03	10·92	9·4	
	Formalin ,, ..	11·11	0·65	11·76	5·5	
	Metal buckets ..	9·69	1·39	11·08	12·5	
26–1–16	Untreated pots ..	11·20	0·76	11·96	6·4	
	Smoked ,, ..	11·55	0·51	12·06	4·2	
	Limed ,, ..	11·48	0·75	12·05	4·7	
	Formalin ,, ..	10·30	0·90	11·20	8·0	
	Metal buckets ..	10·82	1·28	12·10	10·6	
27–1–16	Untreated pots ..	9·90	1·85	11·75	15·7	
	Smoked ,, ..	11·88	0·53	12·41	4·3	
	Limed ,, ..	10·34	0·75	11·09	6·8	
	Formalin ,, ..	10·06	1·33	11·39	11·9	
	Metal buckets ..	10·80	1·69	12·49	13·5	
28–1–16	Untreated pots ..	9·95	1·40	11·35	12·3	
	Smoked ,, ..	11·87	0·66	12·53	5·3	
	Limed ,, ..	11·10	0·82	11·92	6·9	
	Formalin ,, ..	10·58	1·47	12·05	12·2	
	Metal buckets ..	10·00	1·53	11·53	13·3	
29–1–16	Untreated pots ..	10·34	1·39	11·73	11·9	
	Smoked ,, ..	11·30	0·73	12·03	6·1	
	Limed ,, ..	11·52	0·76	12·28	6·2	
	Formalin ,, ..	9·64	1·72	11·36	15·1	
	Metal buckets ..	0·36	1·69	12·05	14·0	
30–1–16	Untreated pots ..	10·03	1·22	11·25	10·9	
	Smoked ,, ..	11·39	1·07	12·46	8·6	
	Limed ,, ..	10·16	0·75	10·91	6·9	
	Formalin ,, ..	9·83	1·88	11·71	16·1	
	Metal buckets ..	10·13	1·02	11·15	9·1	
31–1–16	Untreated pots ..	11·03	1·45	12·48	11·6	
	Smoked ,, ..	12·42	0·87	13·29	6·5	
	Limed ,, ..	11·36	0·67	12·03	5·6	
	Formalin ,, ..	8·96	2·38	11·34	21·0	
	Metal buckets ..	8·21	1·43	9·64	14·8	
1–2–16	Untreated pots ..	10·48	1·47	11·95	12·3	
	Smoked ,, ..	11·31	1·00	12·31	8·1	
	Limed ,, ..	11·11	0·76	11·87	6·4	
	Formalin ,, ..	10·28	2·63	12·91	20·4	
	Metal buckets ..	10·40	1·20	11·60	10·4	

Date	Method of collection	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar	Remarks
2–2–16	Untreated pots ..	8·96	2·71	11·67	23·2	
	Smoked ,, ..	11·63	1·10	12·73	8·6	
	Limed ,, ..	10·29	1·47	11·76	12·5	
	Formalin ,, ..	9·95	1·45	11·40	12·7	
	Metal buckets ..	10·39	1·11	11·50	9·6	
4–2–16	Untreated pots ..	10·59	1·66	12·25	13 5	
	Smoked ,, ..	10·28	1·66	11·94	13·9	
	Limed ,, ..	11·50	0·86	12·36	7·0	
	Formalin ,, ..	9·13	1·64	10·77	15·2	
	Metal buckets ..	10·47	1·39	11·86	11·7	
5–2–16	Untreated pots ..	7·29	4·00	11·29	35·4	
	Smoked ,, ..	9·77	1·14	10·91	10·4	
	Limed ,, ..	10·02	1·12	11·14	10·0	
	Formalin ,, ..	9·99	1·47	11·46	12·8	
	Metal buckets ..	10·49	1·49	11·98	12·4	
6–2–16	Untreated pots ..	..	..	..	..	
	Smoked ,, ..	6·77	2·40	9·17	26·2	
	Limed ,, ..	..	..	..	..	Warm spell of weather.
	Formalin ,, ..	9·20	1·74	10·94	16·0	
	Metal buckets ..	10·39	1·26	11·65	10·8	
7–2–16	Untreated pots ..	..	..	..	..	
	Smoked ,, ..	10·37	1·92	12·29	15·6	
	Limed ,, ..	..	..	..	..	
	Formalin ,, ..	10·00	1·69	11·69	14·5	
	Metal buckets ..	10·43	1·31	11·74	11·2	
8–2–16	Untreated pots ..	..	..	..	..	
	Smoked ,, ..	12·18	1·53	13·71	11·1	
	Limed ,, ..	11·87	0·78	12·65	6·2	
	Formalin ,, ..	..	..	..	..	
	Metal buckets ..	11·29	1·51	12·80	11·8	
10–2–16	Untreated pots ..	10·58	1·25	11·83	10·6	
	Smoked ,, ..	..	..	..	..	
	Limed ,, ..	9·97	0·54	10·51	5·1	
	Formalin ,, ..	..	..	..	..	
	Metal buckets ..	11·41	0·87	12·28	7·1	
11–2–16	Untreated pots ..	10·43	2·32	12·75	18·2	
	Smoked ,, ..	11·67	1·82	12·49	14·6	
	Limed ,, ..	13·58	0·63	14·21	4·4	
	Formalin ,, ..	..	..	..	..	
	Metal buckets ..	..	..	..	..	
12–2–16	Untreated pots ..	12·40	1·53	13·93	11·0	
	Smoked ,, ..	11·10	2·56	13·66	19·0	
	Limed ,, ..	11·31	0·51	11·82	4·3	
	Formalin ,, ..	12·00	1·78	13·78	12·9	
	Metal buckets ..	12·36	1·35	13·71	9·9	

Date	Method of collection	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar	Remarks
13–2–16	Untreated pots ..	13·46	1·43	14·89	9·6	
	Smoked ,, ..	11·02	1·49	11·51	11·9	
	Limed ,, ..	12·92	1·03	13·95	7·4	
	Formalin ,, ..	11·31	1·51	12·82	11·8	
	Metal buckets ..	12·61	1·66	14·27	11·6	
7–2–16	(*a*) Untreated pots	10·63	2·00	12·63	15·8	
	(*b*) do. ..	8·71	3·57	12·28	29·0	
	(*c*) do. ..	8·14	2·27	10·41	21·8	
	(*d*) do. ..	10·37	2·27	12·64	18·0	
	(*e*) do. ..	9·97	2·12	12·09	17·5	
14–2–16	(*a*) Untreated pots	9·32	2·04	11·36	18·0	
	(*b*) do. ..	11·96	1·51	13·47	11·2	
	(*c*) do. ..	9·76	2·27	12·03	18·9	
	(*d*) do. ..	10·05	2·56	12·61	20·3	
	(*e*) do. ..	10·39	3·12	13·51	23·1	

The following series of experiments were designed to test more accurately the effect of various methods of collecting the juice. Three to four litres of juice were collected in the evening, well mixed, and analysed. The following five series of tests were then prepared at about 9 P.M.

1. *Untreated pots.* 8 earthenware pots, such as the tappers use, were taken, and 800 c.c. of juice added to each. These pots received no treatment.

2. *Smoked pots.* Exactly as under 1, but each of the pots was smoked by the cultivators in the usual way.

3. *Limed pots.* Exactly as under 1, but lime was put into each pot first.

4. *Formalin pots.* Also like 1, but each pot treated with formalin as on page 77.

5. *Metal buckets.* 800 c.c. of juice put into each of 8 metal buckets.

There were thus 40 receptacles, 8 in each series.

The 40 receptacles were then put in a big galvanized iron tank well off the ground, so that they would not be disturbed by jackals, etc. In the morning about 9 A.M. the juice of each series was collected together, and from the 5 lots of juice so collected a sample was taken for analysis. The temperature of each sample was also taken. This method of experimenting ensured that the juice taken in each series of tests was of the same composition to begin with.

The following table summarizes the results obtained in each of the three nights on which this series was carried out.

14-2-16. About 34,000 c.c. juice collected at 9 P.M. Its analysis is set out below. 800 c.c. was put into each of the 8 pots of each 5 series, *i.e.*, 40 pots in all.

Date	Method of storage	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar	Temperature of mixed juice °C.
14–2–16 9 P.M.	Original juice ..	13·58	1·43	15·01	9·5	18·5
15–2–16 9 A.M.	Untreated pots ..	10·27	4·35	14·62	30·0	22·5
	Smoked ,, ..	11·02	3·12	14·14	22·1	21·5
	Limed ,, ..	13·61	1·33	14·94	8·9	21·0
	Formalin ,, ..	11·16	3·12	14·28	21·9	21·9
	Metal buckets ..	11·88	2·78	14·66	19·0	23·0

15-2-16. About 22,000 c.c. juice was collected at 9 P.M. Its analysis is set out below. 500 c.c. was put into each of the 8 pots of each 5 series exactly as above.

15–2–16 9 P.M.	Original juice ..	12·77	1·69	14·46	11·7	20·5
16–2–16 9 A.M.	Untreated pots ..	8·01	6·66	14·67	45·4	20·6
	Smoked ,, ..	9·95	5·00	14·95	33·4	22·3
	Limed ,, ..	12·39	1·53	13·92	11·0	21·0
	Formalin ,, ..	10·68	3·84	14·52	26·4	21·2
	Metal buckets ..	10·60	3·57	14·17	25·2	21·5

18-2-16. The total volume of juice collected at night was not recorded, but its analysis is set out below. An equal quantity was put into each of 8 pots of each 5 series exactly as above.

18–2–16 9 P.M.	Original juice ..	13·15	1·56	14·71	10·6	15·0
19–2–16 9 A.M.	Untreated pots ..	10·52	3·44	13·96	24·6	18·1
	Smoked ,, ..	11·70	2·00	13·70	14·6	18·0
	Limed ,, ..	12·23	0·80	13·03	6·1	17·7
	Formalin ,, ..	12·11	1·64	13·75	11·9	18·0
	Metal buckets ..	10·47	3·33	13·80	24·1	17·8

The results of these series of experiments are very definite. It is quite obvious that lime keeps the juice almost perfectly.

In the course of other work a certain amount of data was also accumulated, showing the effect of smoking, liming, and formalin treatment on the quality of juice collected.

The work on *ola* juice (that is the juice which falls from the tree during the day time), described on pp. 87–92, shows that liming has a truly wonderful effect. Formalin there also had a marked effect, though it is seen to be much inferior to lime. The untreated *ola* juice, *i.e.*, simply collected in unsmoked pots, will be seen to be practically all useless for sugar production, the ratio of reducing to total sugar frequently being above 50.

It will be convenient to insert here a few analyses showing the effect of the use of lime on *dokat* juice. *Dokat* juice is usually much inferior to *jiran* juice. Lime seems to have a very marked effect in improving its quality. In the following table are also included analyses of *dokat* juice collected by the cultivators in their own way.

Dokat juice.

Date	Treatment	Sp. gr.	GM. PER 100 C.C.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total sugar	
20–2–16	Cultivator's ..	1·046 (27°C.)	9·16	2·27	11·43	19·9
	Limed ..	1·053 (27°C.)	12·45	0·63	13·08	4·8
21–2–16	Cultivator's ..	1·056 (26°C.)	10·64	2·63	13·27	19·8
	Limed ..	1·054 (25°C.)	11·19	0·66	11·85	5·6

Conclusions.

1. *Effect of smoking the pots.* On referring to the tables we must particularly consider the ratio of reducing sugar to total sugar as this is the test by which to judge the results.

The lower the figure expressing the ratio the more beneficial is any particular treatment. As compared with the untreated pots it will be seen that the smoking has an extremely beneficial effect. It seems to give far better results than the use of metal buckets and frequently better than those of formalin.

As compared with lime it would appear on first glancing at the figures on pp. 78–81, that it had given results equally good. As the weather warmed up in February, however, it was seen to be much inferior to lime, and from general observations of many individual juices collected in limed and smoked pots

there is no question as to the inferiority of the smoking process. The results of the experiments set out on pp. 81–82 show clearly that smoking is far inferior to liming, and in those experiments it is rather inferior to the use of formalin or to the method of collecting in metal buckets. There is no doubt that smoke has some preservative effect on the juice and this is being discussed elsewhere.

2. *Effect of liming the pots.* The use of lime in the pots has given very excellent results, and from a consideration of the results on pp. 78–82 is seen to be easily the best method of collection. It preserves the juice in a really wonderful way. Later experiments on the use of lime for preserving the juice gathered during the day and on the good quality of the *gur* made from the limed juice will add further arguments for the adoption of lime treatment in the date sugar districts. The action of lime is worth while explaining. In the juice as ordinarily collected in the gardens are numerous bacteria, yeasts and moulds, all of which destroy the sugar. There are also numerous non-living ferments often secreted by these organisms, which are capable of changing the cane sugar into the less valuable reducing sugars. The use of a preservative such as smoke or formalin will check the development of the living organisms. It will not however prevent the action of a non-living ferment such as invertase which changes cane sugar to the reducing sugar. Lime, however, in addition to being a good sterilizing agent for living organisms, is strongly alkaline. This alkalinity quite prevents the action of the invertase ferment.

In the experiments described on pp. 81–83, it will be seen that the juice treated with lime would appear to have been actually improved in quality by the destruction of reducing sugar. Thus in the experiments of 18–19 February, 1916, the reducing sugar in the original juice was 1·56 per cent.; after storage with lime it was 0·80 per cent. only. The other two experiments show similar but smaller reductions in reducing sugar content after lime treatment. It has been shown by other workers that lime destroys reducing sugar. In our work we have repeatedly observed the disappearance of reducing sugar from juices stored with lime.

3. *Effect of formalin.* In our previous memoir (pp. 386–388) were described some experiments in which formalin was used in the collecting pots as a means of preserving the juice. These experiments were favourable to the use of this substance, but it is to be noted that the formalin used was 10 per cent. in strength.

In the series of experiments described in this paper only 2 per cent. formalin was used (see p. 77).

In the tables on pp. 78–81, it will be seen that formalin has had very little effect. In fact frequently formalin juices were the worst of the series. In the more reliable experiments whose results are tabulated on p. 82, formalin treatment shows a distinct superiority over the smoking treatment. The action of formalin appeared to us to be uncertain. At times it gave excellent results, whilst at other times it seemed actually to hasten the deterioration of the juice.

We must conclude that in the strengths in which we used formalin during the past season it is of very little use. Perhaps in greater amounts it might be worth while using.

4. *Effect of metal buckets.* These unexpectedly gave very disappointing results. More often than not the juice collected in buckets was the worst of the series.

Some preliminary experiments early in the season indicated that the use of the buckets would be very advantageous as the juice collected in them contained over 12 per cent. sucrose and less than $\frac{1}{2}$ per cent. of reducing sugars. In view of the later results, however, it would seem the good quality of juice in these early experiments must be ascribed to the good quality of the juice collected early in the season.

The poor results obtained with buckets were quite unexpected. The most obvious reason which suggests itself in explanation of the poor results is that the porous pots, owing to evaporation from their outer surface, keep the juice much colder than do metal buckets. This would tend to allow less inversion of cane sugar. Since it was anticipated that the juice collected in buckets might be warmer than that collected in pots, the temperature of the juice in each pot of each series was taken on many occasions at the time of its collection in the morning.

There is no regular higher temperature to be noted in the buckets as compared with the earthen pots. The differences as a rule are negligible. Sometimes higher temperatures were obtained in the pots. Thus on the 26th January, 1916, the temperature of the juice in each of the eight smoked pots was 13·0, 13·0, 15·5, 13·2, 14·4, 13·6, 13·8, and 14·4, an average of 13·8°C. The temperature in each of the buckets was 13·0, 12·8, 14·1, 12·0, 13·0, 14·0, 12·8, and 14·4, an average of 12·8°C. Yet reference to the table on page 79 for the same date will show that the ratio of reducing to total sugars is much higher in the case of the metal buckets than in that of the earthen pots, *viz.*, 10·6 as against 4·2. It would seem that there is some other reason for the inferiority of the buckets to earthen pots.

It was perfectly obvious in the course of the experiments that liming was giving excellent results. It was decided, however, to make a few experiments using a larger quantity of lime to see if even better results could be obtained. Gibbs and Pratt[1] in their work on Nipa palms in the Philippine Islands state that they have found an oxidizing enzyme present in the juice which had the power of destroying the cane sugar. They found that a small amount of sodium sulphite added to the lime gave even better results than lime alone, presumably because the oxidizing enzyme was destroyed by the sulphite. It was decided to include in the set of experiments now to be described a test to see if the addition of sulphite to the lime gave better results than lime alone. In the experiment headed " sulphited lime " the lime used had had some sulphur-dioxide gas bubbled through it for some time.

There were thus three series of pots :—

Ordinary amount of lime	8 pots.
Highly limed	8 „
Highly limed and sulphited	8 „

Twenty-four trees yielding *jiran* juice were taken for the experiments, and one pot was attached to each tree on the evening of the 17th February, 1916. The next morning the juice of each series was mixed together into one lot, and a sample of each of the three lots was drawn for analysis. The results for the two evenings on which the work was carried out are set out below :—

Date of analysis	Manner of preservation	Sucrose gm. per 100 c.c.	Reducing sugar gm. per 100 c.c.	Total sugar gm. per 100 c.c.	Ratio reducing sugar to total sugar
17/18–2–16	Limed	10·55	0·68	11·23	6·1
	Heavily limed	9·29	0·30	9·59	3·1
	Heavily limed and sulphited ..	9·93	0·24	10·17	2·4
19/20–2–16	Limed	11·72	0·66	12·38	5·3
	Heavily limed	11·75	0·43	12·18	3·5
	Heavily limed and sulphited ..	11·90	0·57	12·47	4·6

These tests indicate that in the previous experiments with lime we were not using a sufficient quantity of that substance. In each case the heavily limed pots have given a better juice than the pots in which lime was used in a smaller quantity as measured by the ratio reducing sugar to total sugar.

[1] *Phil. Jour. of Sci.*, Series A, 1913, p. 383.

The presence of sulphite in the lime does not seem to have had any beneficial effect.

Recommendation.

The practice of liming the pots should be introduced into palm-sugar-making districts of Bengal. The amount of lime required is so small that its cost would be almost negligible.

(*b*) "Ola" or Day Juice.

The juice used for sugar production is solely collected at night. During the day juice still continues to flow from the cut surface of the tree. Occasionally this is collected and in the evening boiled down. It is so badly fermented, however, that good *gur* is never obtained from it. The treacle obtained is commonly mixed with the good sample of *gur* obtained next morning. Because of its poor quality by far the largest portion of this day or *ola* juice is not collected at all but simply runs to waste.

It may be pointed out that in Madras the day juice as well as the night juice is used for the production of sugar. It would therefore apparently help the Bengal industry if the day juice could be utilized for sugar production.

A number of measurements have been made of the amount of juice flowing from various trees in the day time. These are recorded in the following table :—

Date	Number of trees measured	Total weight of juice in lb.	Average weight of juice per tree in lb.
6–2–16	34	53·7	1·60
7–2–16	7	11·2	1·60
8–2–16	33	48·2	1·50
9–2–16	34	52·0	1·50
11–2–16	8	9·5	1·20
12–2–16	8	9·8	1·20
13–2–16	33	66·0	2·00
14–2–16	8	3·5	0·40
15–2–16	33	55·4	1·70
16–2–16	6	7·0	1·20
17–2–16	5	6·2	1·00
Total ..	210	322·5	1·54

It will be seen that a large number of trees have been measured, and the average weight of juice flowing from them each in the day time in early February is more than 1½lb. One tree in one day gave 4½lb., but of course this is an exceptional amount.

In order to show the proportion of the juice flowing from the same tree during the night and during the day the following figures are given :—

Date	Number of trees measured	Total weight of juice in lb.		Average weight of juice (in lb.) per tree	
		Night juice	Day or *ola* juice	Night juice	Day or *ola* juice
11–2–16	8	53·0	9·5	6·6	1·20
12–2–16	8	44·7	9·8	5·6	1·20
13–2–16	8	48·4	11·9	6·0	1·50
14–2–16	8	49·9	3·5	6·2	0·40
15–2–16	8	47·3	10·8	5·9	1·30
16–2–16	6	25·7	7·0	4·3	1·20
Total ..	46	269·0	52·5	5·8	1·14

The table indicates that if the day juice flowing from the tree could also be used for sugar production the out-turn per tree would be increased by $\frac{52·5 \times 100}{269}$ or almost 20 per cent. At present the majority of the day juice runs to waste, the cultivators collecting day juice only from those trees which yield considerable quantities. Taking the Bengal production of palm sugar as 100,000 tons annually, the loss through non-collection of the day juice amounts to about 20,000 tons annually.

Another point in favour of collecting this day juice is that it is considerably richer in sugar than is the night juice. In the previous memoir on palm sugar one of us showed that the amount of sugar in the juice tended to increase when the volume of juice decreased and *vice versâ*.

We have a large mass of evidence showing that the day juice is richer in sugar than the night juice, but the following few results will illustrate the point :—

Date	Specific gravity		Total sugar in juice gm. per 100 c.c.	
	Night juice	Day juice	Night juice	Day juice
9–2–16	1·055 (13·5°C.)	1·063 (18°C.)	12·63	14·00
11–2–16	1·055 (20°C.)	1·061 (22°C.)	12·96	14·07
12–2–16	1·056 (14°C.)	1·065 (18°C.)	12·36	14·52
13–2–16	1·054 (21°C.)	1·063 (23°C.)	12·40	13·82
14–2–16	1·055 (11°C.)	1·072 (23°C.)	12·92	15·55
15–2–16	1·055 (23°C.)	1·063 (24°C.)	13·00	14·71

It is therefore plain that by collecting all the day juice we should not only increase our yield of juice by 20 per cent., but the juice obtained would contain from 10 to 20 per cent. more sugar.

It has already been pointed out that the reason why so much of the day juice runs to waste is because it is so badly fermented that a crystalline solid *gur* cannot be obtained from it. On concentration it gives simply a liquid mass of molasses.

A series of experiments were therefore started to see if it were possible to improve the quality of the day juice. In the first place the effect of formalin in preserving the juice was tried.

Sixteen new earthen pots such as the cultivators use for juice collection were taken. On the morning of the 22nd January, 1916, eight of these pots had 5 c.c. of a dilute formalin solution (50 c.c. of commercial formalin diluted to 1000 c.c.) added to each. The remaining eight pots received no treatment. All the 16 pots were then put in position on 16 different trees for juice collection. In the evening the juice from the untreated pots was collected into one sample and the juice from the formalin series into another sample. A sample of each juice was drawn for analysis. The experiment was carried out for some days with the results set out in the following table :—

Date	Treatment	Specific gravity	GM. PER 100 C.C.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total	
22–1–16	Untreated ..			Not analysed.		
	Formalin ..	1·050	8·57	3·22	11·79	27·2
23–1–16	Untreated ..	....	5·69	3·84	9·53	40·3
	Formalin ..	....	9·50	3·57	13·07	27·3
24–1–16	Untreated ..	1·052 (24°C.)	6·36	5·55	11·91	50·9
	Formalin ..	1·045 (24°C.)	7·33	2·86	10·19	28·0
25–1–16	Untreated ..	1·053 (25°C.)		Not analysed.		
	Formalin ..	1·059 (24·5°C.)	10·97	4·54	15·51	29·3
27–1–16	Untreated ..	1·049 (27·5°C.)	5·97	4·34	10·31	42·1
	Formalin ..	1·053 (27°C.)	10·06	2·50	12·56	19·9
28–1–16	Untreated ..	1·054 (26°C.)	5·01	5·88	10·89	54·0
	Formalin ..	1·057 (26°C.)	10·47	2·94	13·41	22·0
29–1–16	Formalin ..	....	11·49	2·12	13·61	15·6
31–1–16	Formalin ..	....	7·36	4·54	11·90	38 0
1–2–16	Formalin ..	....	6·93	4·17	11·10	27·0
2–2–16	Formalin ..	....	6·84	5·88	12·72	46·2

These experiments show that by the use of quite small amounts of formalin the quality of the day or *ola* juice can be considerably improved. At the same time there is room for greater improvement. We frequently collected the day juice in limed pots and always obtained extraordinarily good results.

A series of experiments was therefore put up to test the comparative merits of the liming and formalin treatments. The liming was carried out by smearing the inside of the pots with lime cream. The formalin treatment was carried out as in the previous series of experiments. Eight trees were selected for the experiments and the cut surface of each so modified that two bamboo collecting spouts could be inserted into each. In this way two pots could be attached to each tree. The idea of this procedure was that probably the juice flowing into each of the two pots could be of the same composition. A few experiments made to test this point showed that the juice flowing from different portions of the same cut surface was liable to considerable variation in composition. The experiments, however, are all given for what they are worth. In the table on each day is also recorded the analysis of some *ola* juice collected by the cultivator in his ordinary way. This is called untreated.

Date	Treatment	Specific gravity	GM. PER 100 C.C.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total sugar	
5-2-16	Formalin ..	1·047 (23·5°C.)	6·94	3·82	10·76	35·5
	Limed ..	1·047 (23·5°C.)	8·57	1·95	10·52	18·5
	Untreated ..	1·039 (26°C.)	..	7·41	..	..
6-2-16	Formalin ..	1·057 (24°C.)	10·95	2·35	13·30	17·7
	Limed ..	1·061 (24·5°C.)	11·65	1·88	13·53	13·9
	Untreated ..	1·051 (26°C.)	small	9·51	..	..
7-2-16	Formalin ..	1·062 (25·5°C.)	13·86	2·09	15·95	13·1
	Limed ..	1·065 (25·5°C.)	13·95	0·99	14·94	6·6
	Untreated ..	1·056 (26°C.)	small	10·51	..	..
8-2-16	Formalin ..	1·063 (16·5°C.)	13·12	0·99	14·11	7·0
	Limed ..	1·062 (17°C.)	12·80	0·66	13·46	4·9
	Untreated ..	1·052 (15°C.)	9·06	2·06	11·12	18·5
9-2-16	Formalin ..	1·064 (19°C.)	13·47	0·80	14·27	5·6
	Limed ..	1·062 (17°C.)	12·67	0·58	13·25	4·4
	Untreated ..	1·062 (18°C.)	10·55	2·29	12·84	17·8

Date	Treatment	Specific gravity	Gm. per 100 c.c.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total sugar	
11–2–16	Formalin ..	1·061 (22°C.)	12·60	1·49	14·90	10·6
	Limed ..	1·061 (22°C.)	12·75	1·29	14·04	9·2 *
	Untreated ..	1·061 (22°C.)	5·89	6·69	12·58	53·2
12–2–16	Formalin ..	1·064 (18°C.)	12·32	2·13	14·45	14·8
	Limed ..	1·065 (18°C.)	13·32	1·26	14·58	8·6
	Untreated ..	1·077 (17°C.)	10·06	7·15	17·21	41·6
13–2–16	Formalin ..	1·062 (22°C.)	12·12	1·67	13·79	12·0
	Limed ..	1·063 (23°C.)	12·57	1·27	13·84	9·2
	Untreated ..	1·062 (22°C.)	8·08	5·22	13·31	39·2
14–2–16	Formalin ..	1·072 (23°C.)	13·28	2·82	16·10	17·5
	Limed ..	1·072 (23°C.)	13·28	1·72	15·00	11·5
	Untreated ..	1·053 (24°C.)	4·60	7·31	11·91	61·4
15–2–16	Formalin ..	1·062 (24°C.)	12·93	1·80	14·73	12·8
	Limed ..	1·065 (24°C.)	13·55	1·15	14·70	7·8
	Untreated ..	....	..	..	..	..
16–2–16	Formalin ..	1·067 (23°C.)	12·35	2·34	15·69	21·3
	Limed ..	1·061 (24°C.)	10·46	2·35	12·81	18·3
	Untreated ..	....	..	..	..	..
17–2–16	Formalin ..	1 062 (19°C.)	12·51	..	..	..
	Limed ..	1·059 (19°C.)	12·90	0·96	13·86	6·9
	Untreated ..	....	..	..	..	..

* No more lime added through oversight.

A study of the ratio reducing sugar to total sugar in the last column shows the extremely bad quality of the untreated juice. It also shows that liming is much superior to formalin as a means of improving the quality of the *ola* juice.

A few other odd analyses are here appended of *ola* juice which was collected in limed pots.

Date	Treatment	Specific gravity	Gm. per 100 c.c.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total sugar	
30–1–16	Limed ..	1·055 (23·5°C.)	10·72	1·29	12·01	10·7
31–1–16	Limed ..	1·050 (21·5°C.)	9·11	2·32	11·43	20·3
2–2–16	Limed ..	1·054 (24°C.)	9·64	2·79	12·43	22·4
10–2–16	Limed ..	1·055 (23°C.)	12·25	0·67	12·92	5·2
18–2–16	Limed ..	1·060 (21°C.)	11·83	0·60	12·43	4·8

We made a number of attempts to make *gur* from *ola* or day juice. These always succeeded in the case where the juice had been collected in limed pots.

We obtained a good crystalline *gur* much to the astonishment of the tappers who had never seen good *gur* made from *ola* juice before.

Our attempts to make *gur* from ordinary untreated *ola* juice always failed. From formalin treatment of *ola* juice we frequently got excellent *gur*, but on a number of occasions we met with failures.

Ola juice which has been limed need not be boiled into *gur* at once. This is fortunate as otherwise the cultivator in order to make *gur* from *ola* juice would have to make two boilings per day. The juice can safely be kept till next morning without deterioration and can then be mixed with the juice collected at nights. The following table shows the analysis of three *ola* juices collected in lime-treated pots. The juices were kept till next day, a period about 17 hours, and again analysed. It will be seen there was practically no deterioration of the quality of the juice in any case.

Juice	Date	Specific gravity	GM. PER 100 C.C.			Ratio reducing sugar to total sugar
			Sucrose	Reducing sugar	Total sugar	
No. 1 ..	16–2–16	1·061 (24°C.)	12·00	1·88	13·88	13
	17–2–16	1·061 (26°C.)	12·03	1·74	13·77	13
No. 2 ..	17–2–16	1·054 (19·5°C.)	10·41	1·66	12·07	14
	18–2–16	1·053 (24°C.)	10·44	1·63	12·07	13
No. 3 ..	19–2–16	....	12·05	0·46	12·51	4
	20–2–16	1·058 (22°C.)	12·11	0·48	12·59	4

Recommendation.

The work under this head points to the quite definite conclusion that, if the practice of liming the pots be introduced, a considerable increase, probably of the order of 20 per cent. of *gur* outturn, could be obtained, because it would be possible to use the day juice for *gur*-making.

(*c*) EFFECT OF WASHING THE CUT SURFACE OF THE TREE ON THE QUALITY OF THE JUICE.

We have shown that liming the pots is the best means of preserving the juice. A number of experiments were carried out with the idea of finding out how long juice would keep good in limed pots. We have found that if sufficient lime be used the juice may be kept with loss of sucrose for many weeks. The reducing sugars practically disappear. In the case of juices which had been stored with an insufficiency of lime we obtained a peculiar gum fermentation. The sucrose completely disappeared, being replaced by a

dextro-rotatory gum, leaving the rotation of the solution almost the same as before fermentation. Much acetic and some formic acid were produced and there was a vigorous evolution of gases. The enquiry into the nature of this fermentation was discontinued on the deputation of the senior author to the United Provinces. When special precautions have been taken to clean carefully the cut surface, juices have been obtained which contained practically no sugar except cane sugar. Such a juice is of course very desirable. The juices actually obtained in practice however contain an appreciable amount of the other and less desirable sugars—glucose and lævulose. Since the limed juices also contain these other sugars, it would seem probable that the juice deteriorates before it reaches the collecting pots perhaps owing to the dirtiness of the cut surface and spouts. It was therefore considered of interest to try the effect of washing the cut surfaces and spouts of some trees and to compare the juice obtained with that of juice from unwashed trees. The trees to be washed were first brushed with a brush made from a palm leaf stalk as usually carried by the cultivator and the surface then washed with water. The table sets out the results obtained.

No. of trees	Date	Kind of juice	Treatment	Specific gravity	gm. per 100 c.c.			Ratio reducing sugar to total sugar
					Sucrose	Reducing sugar	Total sugar	
18	6-2-16	*Ola*	Limed pots, surface not washed ..	1·051 (23°C.)	6·47	4·13	10·60	39·0
15	,,	,,	Limed pots, surface washed..	1·053 (23°C.)	11·37	1·33	12·76	10·5
18	7-2-16	,,	Limed pots, surface not washed ..	1·057 (25°C.)	12·38	1·12	13·50	8·3
5	,,	,,	Limed pots, surface washed..	1·065(25·5°C	13·95	0·99	14·94	6·6
22	8-2-16	,,	Limed pots, surface not washed ..	1·056 (17°C.)	11·67	0·84	12·51	6·7
5	,,	,,	Limed pots, surface washed..	1·062 (17°C.)	12·80	0·66	13·46	4·9
25	9-2-16	,,	Limed pots, surface not washed ..	1·055 (17°C.)	11·19	1·05	12·24	8·6
9	,,	,,	Limed pots, surface washed..	1·062 (17°C.)	12·67	0·58	13·25	4·4

No. of trees	Date	Kind of juice	Treatment	Specific gravity	GM. PER 100 C.C.			Ratio reducing sugar to total sugar
					Sucrose	Reducing sugar	Total sugar	
25	13-2-16	*Ola*	Limed pots, surface not washed ..	1·061 (22°C.)	11·90	1·62	13·52	12·0
8	,,	,,	Limed pots, surface washed..	1·063 (23°C.)	12·57	1·27	13·84	9·2
25	14-2-16	,,	Limed pots, surface not washed ..	1·055 (24°C.)	8·19	3·51	11·70	30·0
8	,,	,,	Limed pots, surface washed..	1·027 (23°C.)	13·28	1·72	15·00	11·5
25	15-2-16	,,	Limed pots, surface not washed ..	1·055 (24°C.)	8·22	4·52	12·74	35·5
8	,,	,,	Limed pots, surface washed..	1·065 (24°C.)	13·55	1·15	14·70	7·8
	17-2-16	*Dokat*	Smoked pots, surface not washed ..	1·052 (25°C.)	6·28	7·91	14·19	55·7
			Smoked pots, surface washed	1·052 (26°C.)	8·36	3·80	12·16	31·2
	18-2-16	,,	Smoked pots, surface not washed ..	1·048 (18°C.)	8·62	1·98	10·60	18·7
			Smoked pots, surface washed	1·048 (17°C.)	8·60	2·07	10·67	19·4
	20-2-16	,,	Limed pots, surface not washed	1·056(26·5°C.	12·22	1·52	13·74	11·1
			Limed pots, surface washed..	1 053 (27°C.)	12·45	0·63	13·08	4·8
	21-2-16	,,	Limed pots, surface not washed	1·059 (25°C.)	12·48	1·31	13·79	9·5
			Limed pots, surface washed..	1·059 (25°C.)	11·19	0·66	11·85	5·6

It will thus be seen that the cleaning of the cut surface has had a distinctly beneficial effect in the case of *ola* and *dokat* juice. With *jiran* juice our experience was that the effect was not so marked, but the results have not been recorded here. The tappers raised the objection that much time would be required to clean the trees. This is not so, however,

since one tapper cut, cleaned, and washed 20 trees before us in 80 minutes. The time also included the attaching of the pots.

Recommendation.

We would therefore recommend that the tappers be encouraged to clean the cut surfaces with water daily especially for *dokat*, *tekat*, and *ola* juice. It is possible that the substitution of dilute formalin for water would give better results.

B. IMPROVEMENTS IN THE QUALITY OF *GUR*.

(*a*) Colour.

Anyone acquainted with the cane and palm sugar industries in India cannot help being struck by the great difference in colour between palm *gur* and cane *gur*. The palm product is very dark, at times almost approaching black in colour. The palm sugar molasses obtained in refining is moreover much darker than the corresponding product from sugarcane. There is no doubt that the dark colour renders palm *gur* unattractive and is one of the reasons why its price is so much lower than that of the cane *gur*.

It has been thought by some that improvement in colour would be obtained by boiling the juice in iron pans instead of earthen pans as is the common practice. Thus Mr. B. C. Basu[1] stated that he prepared *gur* of exceedingly fine quality in iron pans. Mr. H. D. Chatterjee prepared some date palm *gur* in iron pans in Central India and submitted samples to the senior writer. These were brighter in colour than the Bengal palm *gur*, but still they had a characteristic dark colour.

Our own early experience led us to the belief that much sugar was burnt when the earthen pots are used for boiling and that the caramel so formed was a contributory cause to the production of the dark colour.

During the past cold weather we have had much personal experience in the field in making palm *gur* by different methods. The result was that we definitely established the fact that iron or tinned pans though giving a brighter coloured *gur* than the earthen pans yet still produced *gur* with the characteristic dark colour.

The juice itself is normally water white though occasionally some samples have a very faint tinge of brown. Hence the colour of *gur* is not due to a pigment occurring in the juice.

[1] Reports of Department of Land Records and Agriculture, Bengal, 1892–3, pp. 32–33, and 1893–4, pp. 16–17.

Date palm juice, however, is commonly strongly alkaline to litmus when fresh. It is well known that when alkalis are boiled with such sugars as glucose and lævulose black-coloured decomposition products are formed.

Hence it occurred to us that the dark colour of palm *gur* was probably due to the action of the boiling alkaline juice on the reducing sugars contained in it.

We therefore tried the effect of slightly acidifying the palm juice before boiling it. The first experiment was done on a very large scale. 800lb. of juice were taken and put into the boiling pan by the aid of buckets. The juice in each bucket was made just acid in the cold to litmus paper with citric acid. The boiling was then proceeded with. It was soon observed that the liquid was not undergoing the usual darkening. After the furnace had been lighted 1¼ hours, a sample of the syrup was withdrawn. It had a very faint pale golden colour with no sign of darkening whatever. Its specific gravity was 1·115 at 15°C. Ordinary juice when boiled to this density is always brown. Three-quarters of an hour later the density of the syrup was 1·165 at 35°C. and it still only had a pale golden colour.

A local sugar-boiler in our employ—a very aged and experienced man—had difficulty in telling when the boiling was finished, since he had never seen a finished syrup of such a light colour. We however constantly took the temperature of the boiling liquid during *gur*-making and we were thus able generally to tell when the boiling was finished. Our final temperature was usually 242–246°F.(116–119°C.)

The *gur* obtained was of an exceedingly light colour equalling the best quality cane *gur*.

After this success we tried many boilings of juice which we had previously acidified by means of various acids. We used sulphuric acid, hydrochloric acid, alum, extract of tamarind fruits, juice squeezed from fresh limes, and the acid liquid left after the souring of milk and the removal of the curd in the native fashion. In all these cases we were able to obtain light-coloured syrups. Hydrochloric acid did not give such good results as the other substances. Hydrochloric acid on boiling with lævulose produces a red colour, and the unsatisfactory results with the acid may have been due to this cause. There was no doubt, however, that the characteristic darkening of ordinary date *gur* was not produced.

Of the above substances perhaps the watery extract of tamarind fruits is the cheapest. Alum is perhaps the most convenient and gives as good

results as anything. For the preparation of a certain light-coloured sweetmeat locally called *patali*, alum and milk are added to the juice before boiling. In the presence of milk a good thick solid scum rises to the surface of the boiling juice and so impurities are more perfectly removed.

The amount of acid substance added to the juice should be such that cold juice rendered neutral to litmus paper with acid becomes just alkaline again on boiling. It requires some experience to hit this point accurately. If too much acid be added then the cane sugar is inverted, that is, changed into the less desirable sugars, glucose and lævulose, and the *gur* obtained will be of a correspondingly poorer quality. Further the juice when made acid very rapidly deteriorates by fermentation.

(*b*) Sugar content.

It has been shown that the practice of liming the pots previous to collection of the juice results in the production of a better quality of juice. The *gur* made from the juice is similarly of a better quality.

Some ordinary *gur* and also *gur* made from limed juice was refined by means of centrifugals at the Tarpur sugar-works. We are indebted to Mr. N. Dutt, the manager, for the loan of centrifugals for this work. The following figures show the results obtained :—

Kind of *gur*	Weight of *gur*	Weight of sugar produced	% of sugar to *gur*
Untreated	2 mds. 17 seers	31 seers	31·0
Limed	1 „ 0 „	23½ „	58·7

In the ordinary country process[1] of refining date palm *gur* the yield of sugar obtained represents 40 per cent. of the *gur* taken, 28 per cent. being obtained in one process and the remaining 12 per cent. only being obtained by re-boiling the molasses from the first process to a second *gur* and refining this. In our figures for the *gur* refined by centrifugals as above, the sugar yield would have been increased if we had re-boiled the molasses. It will be seen that the limed *gur* gave an astonishingly large return of sugar (58·7 per cent.) whereas ordinary *gur* gave only 32 per cent. We do not think that such an extraordinarily favourable result would always be obtained, but it is very suggestive. The sugar made was much praised by local refiners who moreover seemed

[1] See page 362, "The Date Sugar Industry in Bengal," *Mem. Dept. Agric., India, Chem. Series*, vol. II, no. 6.

rather surprised that we were able to make such a good quality sugar by means of centrifugals.[1]

The native refining industry has already been described fully in our previous memoir and full details given of the cost of each operation and the returns for three different factories over a period of three years. More figures have been collected but these only bear out the previous ones. We have the following objections to this process:

1. Large stocks of *gur* have to be kept. This means the locking up of much capital, and also it is probable that the quality of the *gur* deteriorates on storage.

2. It takes several weeks for each lot of *gur* to pass through the refining process. In this time an appreciable amount of sugar gets lost by fermentation. This is especially the case at the end of the refining season when the weather is warming up. It is then a common sight to see sugar fermenting during the refining process. The process has the advantage that it is cheap since there is very little outlay on apparatus.

We asked why centrifugals had never been tried but were informed that they had been and that sugar could not be obtained from date *gur* by their use. We carried out the centrifugal tests described above. These were in every way successful.

Recommendation.

We are fully of opinion that a thorough trial should be given to centrifugals for refining purposes. The refining industry is large enough to warrant their use on a rather large scale.

C. FUEL EXPERIMENTS.

It has frequently been stated that fuel is becoming more and more scarce in the date sugar districts and that this shortage is tending to curtail the sugar output.

The question of the supply of the fuel for the important palm sugar industry in Burma has also been considered by the authorities there. Mr. McKerral[2] suggests the centralization of the *gur*-making operation with the idea of economizing the fuel.

It would therefore be of importance to see if some economy in fuel consumption were not possible. To this end a number of experiments

[1] We have been told that in the season 1916–17 centrifugals have been used at one refinery at Kotechandpur and with excellent results.

[2] *Bulletin* No. 3, 1910, *Department of Agriculture, Burma.*

have been carried out with the furnaces as used by the cultivators to determine the amount of fuel used in producing one maund of *gur*.

We think the experiments show that considerable economy of fuel could be effected.

The fuel in common use in the date sugar districts is wood and the dried palm leaves. We have never seen coal in use by the people. In the description of the tapping process on page 72, it will be seen that in preparing the trees a large number of leaves are stripped off. These are all kept and are largely used as fuel. In fact they are almost the sole fuel in use until the middle or end of December. *Rahar* or *arhar* (*Cajanus indicus*) stalks and the wood left after the retting of jute are occasionally used. Thus the growth of such crops as *rahar* and jute helps to solve the fuel problem. *Rahar* can be grown quite conveniently in the date sugar plantations.

The preliminary steps in our fuel enquiry were therefore directed towards investigating the actual amount of date palm leaves or wood used by the cultivator in the production of a maund of *gur*. We then had to find what was a fair value to put upon the wood. In this we had much difficulty. Enquiries among tappers as to the value of fuel used in the production of *gur* showed that they estimated the expenditure in fuel at from 11 annas to 21 annas per maund (82lb.) of *gur* made.

The experiment detailed below points to the fact that about $6\frac{1}{2}$ to 10 maunds of wood are normally used by the cultivators in the production of 1 maund *gur*.

Wood seems to sell at Kotechandpur at about R. 1-5 per cart-load delivered. It has to be dried before use, and hence loses a good deal of weight. The wood costs 6 annas per cart-load for splitting. We actually weighed a number of cart-loads being sold in the market at Kotechandpur, and the table shows the cost per maund of undried wood.

Weight per cart-load	Price per cart-load	Price per cart-load including charge for splitting	Price per md. (82lb.) unsplit wood	Price per md. (82lb.) split wood
lb.	R. A. P.	R. A. P.	R. A. P.	R. A. P.
559	1 5 0	1 11 0	0 3 0	0 3 10
469	1 5 0	1 11 0	0 3 7	0 4 7
473	1 5 0	1 11 0	0 3 5	0 4 5
684	1 5 0	1 11 0	0 2 6	0 3 2
504	1 4 0	1 10 0	0 3 2	0 4 1
398	0 13 0	1 3 0	0 2 7	0 3 10

The average price per maund of split wood therefore works out at 4 annas, and for unsplit at rather over 3 annas. At the same time it must be remembered that the wood dries considerably before use and these prices would have to be increased in consequence. The tapper in Jessore, however, does not admit that this wood costs him as much as the above figures would make out. In the first place he points out that the splitting is done by his own family and he does not have to pay for it. Further they say that they collect their wood before the beginning of the cold weather and it is then much cheaper. They would put the cost of their wood at not more than 2 annas per maund and perhaps less. We do not think there are many places in Bengal where 2 annas a maund would be a fair rate to put on wood.

Enquiries in Goalundo Subdivision of the Faridpur District in March, 1916, elicited the information that wood costs there Rs. 3 per cart-load of 13 maunds of 60lb. each, splitting costs 8 annas per cart-load, so that the price per *pucca* maund of 82lb. works out at 5 annas 7 pies. Coal apparently costs there very little more than wood.

We carried out fuel tests in various kinds of furnaces :—

1. *The ordinary country furnaces.* These invariably consist of holes in the ground over which the earthen boiling pots are supported (*see* Plate VII of our previous memoir). The cultivators commonly have 2 or 4 boiling pots on one furnace. Sometimes only one boiling pot is used. We have seen as many as 16 boiling pans on one furnace. The tests here described were carried out on furnaces carrying one, two, and four boiling pans, and were mostly done at tappers' furnaces, the man carrying out his work in the usual way. We, however, weighed the palm juice used and the *gur* produced, and also the amount of fuel he actually used, and kept a record of time consumed in the making of the *gur*. We also had a furnace of our own erected exactly on the native plan. Tests with this are also included in the tables.

2. *A modified country furnace.* This was a furnace we designed ourselves. We were concerned to alter the native process as little as possible. We used earthen pans to boil the juice in, but we deepened the furnace somewhat and put in iron bars half way down to burn the fuel on so that there should be an underdraught. We also attached a chimney made from kerosene tins to the furnace. The furnace as finally adopted took two boiling pots side by side. We originally tried to have three pots, one behind the other in series, but we could not get good results in this way. With the furnace as finally adopted we had very efficient draught and we obtained good results.

Fig. 1. THE MAPLE SUGAR OUTFIT, SHOWING EVAPORATOR.

Fig. 2. THE MAPLE SUGAR OUTFIT.

Fig. 1. THE MAPLE SUGAR OUTFIT, SHOWING SUGARING ARCH.

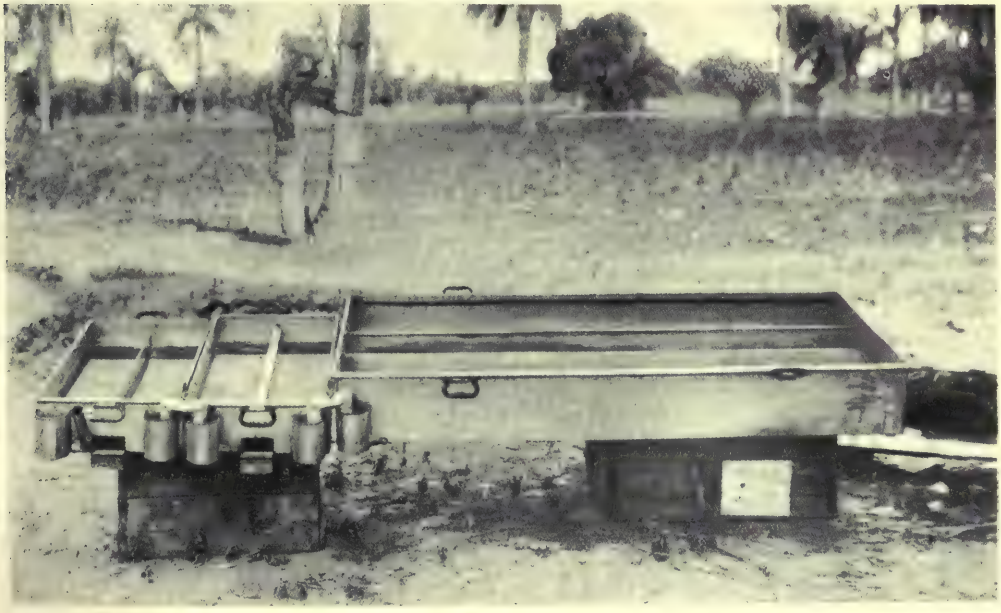

Fig. 2. THE MAPLE SUGAR OUTFIT—EVAPORATOR PORTION.

3. *Iron pan.* A shallow iron pan fitted over a furnace just like the tapper's furnace but much bigger in order to accommodate the iron pan. To this furnace we also attached a kerosene-tin chimney.

4. *A modified furnace for iron pan.* The furnace under 3 was subsequently modified by the insertion of fire bars in order to obtain underdraught. Matters were considerably improved by this modification.

5. *An American maple-sugar-making plant.* This was a plant imported from Messrs. Grimm & Co., of Vermont, U. S. A. It is an apparatus in common use in that country for the manufacture of maple sugar and has the reputation of being extremely economical of fuel. Photographs of the plant are to be seen in Plates I and II. The apparatus is portable, and the two furnaces are wholly of iron lined with fire brick. They are of course fitted with fire bars and burn either wood or coal. The evaporating pans (Plate II, fig. 2) are of heavily tinned iron. The juice flows from a storage tank seen in the right of Plate I, fig. 1, through a box which automatically gives any desired rate of flow into the corner of a long pan. This pan has two longitudinal divisions dividing it into three compartments, and its bottom instead of being flat is folded up into longitudinal corrugations in order to give a large heating surface. The juice having entered at the front corner end of one of these compartments flows forward and then through a hole in the neighbouring partition into the middle compartment. It flows back towards the front of the pan again where it is able to pass through a hole in the second partition and go into the third compartment. It flows forward down this compartment. By means of a syphon tube it is then automatically led into a smaller tinned iron pan with a transverse partition. It flows through a hole in the further end of this partition into a second compartment. It thence reaches another syphon and passes over into a third pan exactly similar to the second. Having passed through that the juice has become concentrated to about 1·1 specific gravity. The syphons are supposed to produce a cleaner syrup by not allowing the scum to pass on. The part of the apparatus so far described is called the evaporator. Its object is to concentrate the thin juice rapidly to a syrup, and the process is continuous, the juice as it is concentrating passing along through the pans the whole time and being continually drawn off at the part of the plant nearest the chimney. The hot juice is strained through felt and the syrup placed in the sugaring arch. This consists of a heavily tinned, deep, oblong iron pan set in an iron furnace fitted with fire bars and lined with fire brick. It is seen in the foreground of Plate II, fig. 1. The syrup is here concentrated to the necessary consistency for *gur*-making.

In making *gur* by this plant it will be seen that two furnaces are in use. Of course in the results set out below the fuel figure is the total fuel used in both furnaces.

6. *The sugaring arch* described above was used omitting the preliminary treatment in the evaporator.

The tables below show the results with each type of boiling plant and explain themselves.

1. THE ORDINARY COUNTRY FURNACE.

Tables (*a*), (*b*), and (*c*) set out the results obtained with country furnaces containing one, two, and four boiling pans respectively on each furnace. The tables explain themselves.

As is to be expected the amount of palm juice dealt with per hour is almost exactly proportionate to the number of boiling pans.

Thus a furnace with one boiling pan deals with 20 lb. of juice per hour. If there are two boiling pans, then 40 lb. of juice per hour can be dealt with. With 4 pans about 83 lb. of juice per hour were dealt with.

Proportion of fuel to juice. With only one pan per furnace this varies from 1·65/1·00 to 0·82/1·00 with an average for all the experiments of 1·23.

When the furnace has two boiling pans the proportion varies from 1·45/1·00 to 0·81/1·00 with an average for all the experiments of 0·96.

With 4 boiling pans per furnace the ratio varies from 1·00/1·00 to 0·75/1·00 with an average of 0·87. These figures apply only when wood is used as fuel. Date palm leaves seem to give much better results than wood, since, when they are used, the ratio varies from 0·53 to 0·69 with an average of 0·62.

Proportion of fuel to gur. With one pan per furnace this ratio varies from 15·0/1·0 to 6·8/1·0 with an average of 9·8. When the furnace had two boiling pans the ratio varied from 12·4/1·0 to 7·2/1·0 with an average of 8·6.

With 4 boiling pans on one furnace and wood fuel the ratio varies from 7·3/1·0 to 5·3/1·0 with an average of 6·4. When palm leaves are used as fuel the ratio ranges from 4·8/1·0 to 3·6/1·0 with an average of 4·3.

It is therefore quite obvious that a great wastage of fuel takes place if the boiling be carried out in furnaces having only one or two boiling pans. A furnace fitted with four boiling pans would apparently use only three-fourth the fuel which one fitted with only two boiling pans would in dealing with the same quantity of juice. Putting the value of wood at only 2½ annas per maund this would mean a saving of 5 annas per maund of *gur* on fuel alone.

Possibly the use of a larger number of pans might economize fuel to a larger extent, but obviously there must be a limit, and we do not think that increasing the number of pans beyond four is likely to bring about much further economy. It must be mentioned that the tappers seldom use furnaces containing less than 2 boiling pots but they very commonly use this type. Two boiling pans will deal with the juice of about 30 trees daily, so that if a man only owns this number of trees it means that he cannot use a furnace containing more than this number of boiling pans.

The high fuel value which date palm leaves have here calls for remark. It would seem that one part of date palm leaves is of just as much use for fuel as $1\frac{1}{2}$ parts of wood. The fact that the palm leaves can be completely burnt much more readily may account for its better fuel value. Then no doubt different kinds of wood have different fuel values.

Date palm leaves unfortunately are not available in sufficient quantities to last throughout the whole season for fuel. The leaves used are those removed from the trees in the beginning of the season when the trees are being prepared for tapping. By the middle or end of December this supply of leaves is exhausted, and for the remaining 2 to $2\frac{1}{2}$ months of the season other fuel has to be used.

It will be noticed that no experiments have been recorded in the case of country furnaces in which coal was used as fuel. It was found that coal could not be used in these furnaces owing to the want of underdraught.

(a) Only one boiling pan on furnace.

Date	Furnace used	Kind of fuel	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time of boiling	Juice dealt with per hour	Total sugar in juice %
			lb.	lb.		lb.			hrs.	lb.	
13-1-16 ..	Cultivator's	Wood ..	61·4	7·5	8·2	50·6	0·82	6·8	2·66	23	..
21-1-16 ..	Our furnace	Dried branches and palm leaves ..	..	8·1	..	*57·6	..	7·0	2·75	..	..
25-1-16 ..	Cultivator's	Wood ..	54·6	..	..	59·8	1·09	..	..	..	15·51
25-1-16 ..	Our furnace	,, ..	53·0	6·8	7·8	78·3	1·48	11·5	..	..	..
26-1-16 ..	Cultivator's	,, ..	71·9	8·6	8·4	78·8	1·10	9·2	4·83	15	..
26-1-16 ..	,,	,, ..	64·9	9·5	6·9	77·4	1·19	8·2	3·25	20	12·51
27-1-16 ..	,,	Wood and palm leaves ..	68·4	8·6	8·0	{ †61·6 ‡22·0 }	1·22	9·7	2·50	27	..
27-1-16 ..	,,	Wood	73·0	7·5	9·8	*111·8	1·53	15·0	4·33	17	..
28-1-16 ..	,,	,,	71·3	7·9	9·0	96·8	1·36	12·2	3·17	23	..
28-1-16 ..	,,	,,	57·4	7·7	7·5	61·6	1·07	8·0	2·33	25	11·76
29-1-16 ..	,,	,,	74·4	9·5	7·9	82·9	1·11	8·8	4·50	17	..
29-1-16 ..	,,	,,	63·8	7·9	7·8	72·2	1·13	9·0	3 00	21	..
30-1-16 ..	,,	,,	75.5	7·7	9·8	103·0	1·36	13·4	..	..	10·54
30-1-16 ..	,,	,,	57·2	7·9	7·2	63·4	1·11	8·0	3·25	18	12·01
31-1-16 ..	,,	,,	74·6	9·0	8·2	84·7	1·13	9·4	..	..	11·72
31-1-16 ..	,,	,,	56·5	7·7	7·3	68·9	1·22	8·9	2·75	20	11·43
1-2-16 ..	,,	,,	72·2	8·1	8·8	91·1	1·26	11·2	3·17	23	11·99
1-2-16 ..	,,	,,	73·9	7·7	9·6	81·0	1·10	10·5	2·75	23	11·02
2-2-16 ..	,,	,,	66·2	9·0	7·3	79·9	1·27	8·9	..	..	..
2-2-16 ..	,,	,,	60·3	7·7	7·9	99·0	1·65	12·9	3·90	15	11·36
4-2-16 ..	,,	,,	49·1	6·4	7·7	72·6	1·48	11·4	3·25	15	12·43
AVERAGE			65·0	8·0	8·1	..	1·23	9·8	..	20	..

* Wood wet. † Wood. ‡ Leaves.

(b) Two boiling pans on furnace.

Date	Cultivator's name	Kind of fuel	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time of boiling	Juice dealt with per hour	Total sugar in juice %
			lb.	lb.		lb.			hrs.	lb.	
20–1–16 ..	Haibot	Wood	125·0	....	....	140·8	1·13	....	3·00	42	..
4–2–16 ..	,,	,,	137·7	15·40	8·9	111·3	0·81	7·2	3·50	39	11·35
5–2–16 ..	,,	,,	145·4	16·90	8·6	154·0	1·06	9·1	3·83	48	11·80
6–2–16 ..	,,	,,	137·7	13·90	10·0	112·9	0·82	8·1	3·33	41	11·23
			Same juice as used in sugaring arch on this date.								
7–2–16 ..	,,	,,	96·1	11·21	8·6	139·7	1·45	12·4	2·83	34	11·35
9–2–16 ..	,,	,,	137·1	17·20	7·9	154·2	1·13	9·0	2·84	48	..
10–2–16 ..	,,	,,	140·8	16·70	8·4	127·6	0·91	7·6	4·25	33	..
10–2–16 ..	,,	,,	128·7	15·20	7·8	121·0	0·94	8·0	3·75	34	..
11–2–16 ..	,,	,,	126·7	15·40	8·2	120·1	0·95	7·8	..	..	..
11–2–16 ..	,,	,,	189·6	22·90	8·3	161·7	0·86	7·1	3·75	51	..
			Same juice as used in sugaring arch on this date.								
12–2–16 ..	,,	,,	94·2	11·00	8·6	115·5	1·23	10·5	2·66	36	..
13–2–16 ..	,,	,,	92·4	15·20	6·1	129·8	1·40	8·5	2·75	34	..
15–2–16 ..	,,	,,	85·8	12·30	7·0	103·4	0·83	7·6	..	..	..
AVERAGE			126·0	15·30	8·2	..	0·96	8·6	..	40	..

(c) Four boiling pans on furnace.

Date	Cultivator's name	Kind of fuel	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time of boiling	Juice dealt with per hour	Total sugar in juice %
			lb.	lb.		lb.			hrs.	lb.	
11-12-15..	Kayem	Wood	309·6	41·8	7·4	257*	0·83	6·1	4·00	78	
12-12-15..	,,	,,	350·0	48·0	7·3	352*	1·00	7·3	4·00	88	
13-12-15..	,,	,,	322·0	42·4	7·6	296	0·92	7·0	3·50	92	
20-1-16 ..	Haibot	,,	287·4	40·5	7·1	214	0·75	5·3	3·66	78	
21-1-16 ..	,,	,,	284·0	39 3	7·2	..	..	..	3·50	81	
AVERAGE			310·6	42·4	7·3	..	0·87	6·4	..	83	
11-12-15..	Haibot	Dried palm leaves	360·0	52·4	6·9	190	0·53	3·6	4·33	83	
12-12-15..	,,	,,	314·6	45·5	6·7	216	0·69	4·8	4·00	79	
13-12-15..	,,	,,	325·0	47·2	6·9	206	0·63	4·4	4·00	81	
AVERAGE			333·2	48·3	6·9	..	0·62	4·3	..	81	

* Weight includes 16 lb. leaves.

2. A MODIFIED COUNTRY FURNACE.

This has been described on page 100.

It was designed because it was felt that the greatest defect in the ordinary country furnaces was their want of underdraught. At the same time we wished to see if we could give the cultivators something very like their own furnace to start with but which was nevertheless an improvement. Our furnace cost less than Rs. 2 including the price of the earthen boiling pans.

Uufortunately only one experiment was done with wood fuel, but some half-a-dozen were carried out with coal as fuel. The results obtained were not very satisfactory except with some of the coal fuel experiments. Our general impression however was that the furnace burnt much better than the ordinary country one, but pressure of other work prevented us giving it a fair trial. The results are set out in the table. Two boiling pans were on the furnace in each case.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Remarks
		lb.	lb.		lb.			hrs.	lb.	
7–2–16 ..	Coal	94·6	10 3	9·1	33·0	0·35	3·20	2·5	38 0	
12–2–16 ..	,,	150·9	22·2	6·8	46·2	0·31	2·10	2·8	53·3	
		Same juice as in Chinsurah pan of the date.								
13–2–16 ..	,,	122·1	16·5	7·5	55·0	0·45	3 30	3·4	35·7	
14–2–16 ..	,,	127·4	20·2	6·9	38·1	0·30	1·88	4·0	32·0	
15–2–16 ..	,,	118·6	15·4	7·7	49·9	0·42	3·20	3·0	38·5	Much fuel left over unburnt.
18–2–16 ..	,,	122·8	14·7	8·3	..	..	..	..	..	
21–2–16 ..	,,	..	13·4	..	29·7	..	2·20	..	..	
17–2–16 ..	Wood	137·9	17·4	7·9	169·4	1·23	9·75	5·0	27·6	Wood wet.
		Same juice as used in sugaring arch on that day.								
Average.. omitting wood fuel experiment		125·0	16·3	7·7	..	0·37	2·60	..	38 0	

3 & 4. Experiments with iron boiling pan.

This was a round pan of a very shallow type. It has been found that by the use of a shallow pan a large amount of economy in fuel consumption may be brought about.

The experiments were carried out in two series.

Series I. The iron pan was placed over a furnace exactly like those of the cultivator's but large enough to fit the pan. Thus there was no under-draught. A small chimney made of kerosene tins was however fitted to the furnace at the side opposite the hole into which the fuel was fed.

Series II. The furnace used was a much deeper hole than above, and fire bars were placed across it half way up. It was also fitted with the chimney as before.

Only 4 experiments were carried out under Series I, two being with wood as fuel and two with coal. A larger number of experiments were carried out under Series II. All the results are recorded below :—

Series I. Ordinary country furnace.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Total sugar in juice %
		lb.	lb.					hrs.	lb.	
13–1–16 ..	Wood	305·8	37·6	8·1	265·5	0·87	7·06	..	..	..
28–1–16 ..	,,	471·2	53·7	8·8	474·1	1·00	8·81	6·75	70	11·5
		Same juice as in maple furnace of date.								
Average		..	..	..	..	0·93	7·93	..	..	..
14–1–16 ..	Coal	362·0	44·9	8·1	*310·0	0·86	7·00	5·00	72	11·60
24–1–16 ..	,,	271·6	31·7	8·7	138·6	0·51	4·38	3·42	81	10·85
		Same juice as in maple furnace of date.								

* 22 lb. wood also used.

A review of the results set out in the above table would show that the use of an iron pan on the ordinary local type of furnace possesses no advantage from the point of view of fuel economy over the ordinary method in which two earthen pans are used over a similar kind of furnace. It is further seen that the use of coal was unsuccessful.

The furnace hole was therefore deepened and fitted with fire bars on which to burn the fuel. The results then obtained are set out in the following table.

Series II. Furnace fitted with fire bars.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Total sugar in juice %	Remarks
		lb.	lb.		lb.			hrs.	lb.		
29-1-16 ..	Wood	520·7	59·80	8·7	268·4	0·52	4·50	4·25	122	11·24	
		Same juice as in the maple furnace of date.									
30-1-16 ..	,,	659·6	66·40	9·9	381·5	0·58	5·00	5·75	115	11·62	
		Same juice as in the maple furnace of date.									
12-2-16 ..	,,	373·1	35·20	10·6	206·8	0·56	5·90	3·66	102	12·84	*Gur* lost in transfer.
		Same juice as in the maple furnace of date (probably *gur* yield low).									
13-2-16 ..	,,	505·8	65·80	7·7	334·0	0·66	5·10	5·66	89	12·62	
15-2-16 ..	,,	584·1	74·60	7·8	312·2	0·59	4·60	7·33	80	..	*Gur* lost in transfer.
Average..		528·7	60·36	8·8	300·6	0·57	5·00	..	102	..	..
25-1-16 ..	Coal	329·6	40·50	8·1	154·0	0·47	3·70	4·00	82	11·80	
		Same juice as in maple furnace of date.									
26-1-16 ..	,,	529·8	60·10	8·8	203·9	0·39	3·43	4·60	115	11·24	
		Same juice as in maple furnace of date.									
27-1-16 ..	,,	603·5	60·90	9·9	189·2	0·31	3·10	5·66	107	11·50	
3-2-16 ..	,,	767·4	84·70	9·0	178·0	0·23	2·10	5·66	136	11·74	
4-2-16 ..	,,	812·9	83·80	9·7	195·8	0·24	2·36	7·60	107	11·34	
5-2-16 ..	,,	655·8	64·20	10·6	191·4	0·29	3·00	6·16	106	13·58	
16-2-16 ..	,, (Some wood)	323·8	47·10	6·9	126·7	0·39	2·70	4·50	72	..	
		Same juice as in maple furnace of date.									
Average..		574·7	63·10	9·0	..	1·33	2·91	..	104	..	

It will be seen from the above tables that the introduction of fire bars into the furnace brings about a very large economy in fuel. In the case of wood the ratio fuel/juice is only 0·57 and the ratio fuel/*gur* averages out at 5·0/1·0, that is, 57 lb. of fuel are sufficient to convert 100 lb. of juice into *gur*, or 5 parts of fuel are used in the manufacture of one part of *gur*.

A peculiar point to notice in these experiments with the iron pan is that the proportion of *gur* obtained from the juice is always much lower than with any other system of boiling we tried. Thus on an average 9 parts of juice were required to make one part of *gur*. In the country and maple furnaces the juice to *gur* ratio was only 7 : 8. Frequently we used some of the same juice on the same day for *gur*-making in the iron pan and also in the country or maple furnaces, but the iron pan always gave a distinctly lower yield of *gur*. It seemed to us that the reason was that it was difficult to clean all the *gur* off the pan at the end of the boiling, and therefore the weight of *gur* obtained was always less than it ought to have been. Further, our pan was so large that the men found it difficult to handle and frequently spilt some of the juice out of it.

The decrease in weight may be due to another reason. A considerable time elapses between the interval of removing the pan from the fire and the final transference of *gur* into the *bhars* (earthen storing pots). It is the general custom to allow the *gur* to cool some time before it is transferred into the *bhars*. But in the case of this pan it has been noticed that the temperature of *gur* in the pan after being removed from the fire steadily increases for a time and this increase goes on so far as 120°—123°C. (scarcely below 120°), whereas the general temperature at which the *gur* is taken out as finished is about 115°C. The pan being a metallic one naturally remains hotter as compared to the earthen *jalas* used in the country process. The *gur* made in the iron pan would therefore contain less water, and this would explain the lower out-turn.

5. An American maple-sugar-making plant.

This has been described on page 101.

Owing to the difficulty of obtaining the amount of wood required, most of the experiments were done with coal fuel. A few experiments were made in which wood was mainly used. All the results are set out in the table below.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel		Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Total sugar in juice %	Remarks
		lb.	lb.		lb.				hrs.	lb.		
8–12–15..	Wood	697·0	92·5	7·40	320	Wood	0·50	3·45	5·50	127	..	
	Some coal	..	..	..	80	Coal	0·09	0·86	..	..	..	
							(0·72)	(5·60)	..	..	..	
9–12–15..	Wood	734·0	96·0	7·60	240	Wood	0·33	2·50	..	..	..	
	Some coal	..	..	..	20	Coal	0·03	0·20	..	..	..	
							(0·40)	(3·00)	..	..	..	
10–12–15..	Wood	881·2	108·0	8·15	300	Wood	0 34	2·80	..	..	..	
	Some coal	..	..	..	40	Coal	0·04	0·37	..	..	..	
							(0·44)	(3·72)	..	..	..	
16–12–15..	Wood	752·2	104·0	7·26	440	Wood	0·59	4·27	6·66	113	..	
	Some coal	..	..	..	50	Coal	0·07	0·50	..	..	..	Wood wet, much trouble.
							(0·76)	(5·52)	..	..	..	
17–12–15..	Wood	738·0	98·0	7·53	450	Wood	0·61	4·60	..	..	..	
	Some coal	..	..	..	90	Coal	0·12	0·92	..	..	..	
							(0·91)	(6·90)	..	..	..	
18–12–15..	Wood	804·5	100·0	8·04	640	Wood	0·80	6·40	..	..	12·10	
	Some coal	..	..	..	100	Coal	0·12	1·00	..	..	..	
							(1·10)	(8·40)	..	..	..	
11–1–16 ..	Wood	1,047·0	140·6	7·45	1004·2	..	0·97	7·34	8·33	126	11·52	Furnace still wet. Second day in field.
14–1–16 ..	Wood	1,459·0	198·4	7·35	583	Wood	0·42	2·94	10·16	145	11·60	
	Some coal	..	..	..	319	Coal	0·22	1·60	..	..	..	
							(0·97)	(6·94)				
AVERAGE..		890·0	117·2	7·60	..	..	*0·66	*5·99	..	128	..	

* These results have been obtained after multiplying any coal used in each experiment by 2·5 (many experiments having shown coal to be about 2·5 times as useful as fuel as wood). The figure thus obtained was added to the amount of wood used, and the result is shown in brackets in each case.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel		Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Total sugar in juice %	Remarks
		lb.	lb.		lb.				hrs.			
27–11–15..	Coal	264	36·5	7·23	120 0	..	0·45	3·30	..	..	..	Furnace new and wet. Small amount of juice.
29–11–15..	,,	750	102·0	7·35	240·0	..	0·32	2·35	..	..	..	
19–12–15..	Coal	800	102·4	7·81	190·0	Coal	0·24	1·85	..	..	12·14	
	Some wood	..	..	..	50·0	Wood	0·06	0·50	..	..	..	First day in field. Furnace wet.
10–1–16 ..	Coal	..	102·3	..	283·3	Coal	..	2·80	7·00	..	..	
	Some wood	..	..	..	39·6	Wood	..	..	..	..	..	
12–1–16 ..	Coal	1,394	184·6	7·55	345·0	Coal	0·25	1·99	8·33	166	11·41	
	Some wood	..	..	..	79·0	Wood	0·06	0·43	..	..	..	
13–1–16 ..	Coal	937	124·1	7·55	246·4	Coal	0·26	1·99	6·66	141	11·89	
	Some wood	..	..	..	37·4	Wood	0·04	0·30	..	..	..	
16–1–16 ..	Coal	2,138	298·0	7·17	616·0	..	0·29	2·06	10·50	204	11·30	
17–1–16 ..	,,	2,015	283·0	7·10	607·0	..	0·30	2·14	10·33	195	11·32	
18–1–16 ..	,,	2,137	293·0	7·40	625·0	..	0·29	2·13	..	..	11·34	

Date	Fuel used	Weight of *juice*	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel		Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour	Total sugar in juice %
		lb.	lb.		lb.				hrs.	lb.	
19–1–16 ..	Coal	2,438	303·0	8·04	678·0		0·28	2·23	14·00	174	10·70
					19·8	Wood	..	0·05			
20–1–16 ..	,,	1,682	224·8	7·48	519·0		0·31	2·30	8·42	200	10·86
					22·0	Wood	..	..			
21–1–16 ..	,,	1,214	161·5	7·52	341·0		0·28	2·11	7·25	168	11·80
					22·0	Wood	..	..			
22–1–16 ..	,,	1,269	160·8	7·89	372·0		0·29	2·31	..	..	10·90
					22·0	Wood	..	..			
23–1–16 ..	,,	1,067	128·7	8·30	290·4		0·27	2·26	8·00	133	10·96
					22·0	Wood	..	..			
24–1–16 ..	,,	891	126·9	7·50	321·0		0·36	2·53	7·42	120	10·85
		Same juice as in Chinsurah pan of the date.									
25–1–16 ..	,,	980	130·0	7·54	280·0		0·29	2·20	7·25	135	11·08
		Same juice as in Chinsurah pan of the date.									
26–1–16 ..	,,	1,148	160·4	7·16	330·0		0·29	2·06	8·16	141	11·24
		Same juice as in Chinsurah pan of the date.									
27–1–16 ..	,,	1,271	170·9	7·40	342·1		0·27	2·00	7·33	173	11·50
		Same juice as in Chinsurah pan of the date.									
28–1–16 ..	,,	1,148	147·4	7·92	354·2		0·31	2·40	9·83	117	11·50
29–1–16 ..	,,	1,100	141·7	7·75	351·6		0·32	2·48	..	..	11·24
30–1–16 ..	,,	1,134	145·0	7·86	303·6		0·27	2·09	8·60	132	11·62
31–1–16 ..	,,	1,526	194·9	7·83	420·2		0·28	2·15	9·25	165	11·68
1–2–16 ..	,,	1,204	163·2	7·37	376·2		0·31	2·30	8·83	136	12·29
2–2–16 ..	,,	1,191	150·5	7·93	420·2		0·35	2·83	..	..	11·97
AVERAGE		1,291	159·3	7·60	..		0·30	* 2·38	..	156	..

* Wood used is neglected since difference made is so slight. These results will be considered later.

6. Experiments with the sugaring arch.

As already explained above, this is merely the deep, oblong, finishing pan of the maple sugar furnace. It rests on its own iron furnace which is fitted with fire bars and lined with fire bricks. It is seen in the fore part of Plate II, fig. 1.

The table summarizes the results with this plant.

Date	Fuel used	Weight of juice	Weight of *gur*	Ratio of juice to *gur*	Weight of fuel	Ratio of fuel to juice	Ratio of fuel to *gur*	Time	Juice dealt with per hour.	Total sugar in juice %	Remarks
		lb.	lb.		lb.			hrs.	lb.		
17-2-16 ..	Wood	475·0	59·6	8 0	378·0	0·79	6·30	9·60	50	..	Fuel wet.
		Only one experiment done with wood as fuel.									
6-2-16 ..	Coal	549·1	74·1	7·4	173·8	0·32	2·40	6·83	84	11·23	
		Same juice as per country bain experiment (alum v.H_2 30).									
7-2-16 ..	,,	403·6	55·4	8·0	136·4	0·34	2·46	5·66	71	11·88	
8-2-16 ..	,,	504·9	66·7	7·6	195·8	0·39	2·90	6·00	84	12·38	
		Same juice as in modified country furnace.									
9-2-16 ..	,,	544·1	70·8	7·7	140·8	0·26	1·98	7·33	74	..	
10-2-16 ..	,,	715·4	90·6	7·9	188·1	0·26	2·08	8·00	89	..	
		Same juice as used in country furnace experiment of the date.									
11-2-16 ..	,,	781 0	107·6	7·2	253·0	0·32	2·35	8·42	93	..	
Average .		583·0	77·5	7·6	..	0 31	2·36	..	82	..	

Summary.

The following table summarizes the average results of each method of boiling with wood fuel.

Method of boiling	Ratio of fuel to juice	Ratio of fuel to *gur*	Juice dealt with per hour	Number of experiments
			lb.	
Country system, 1 pan	1·23	9·80	20	21
Country ,, 2 pans	0·96	8·60	40	13
Country ,, 4 ,, ...	0·87	6·40	83	5
Iron pan, country furnace	0·93	7·93	70	2
Iron pan, furnace with fire bars	0·57	5·00	102	5
Maple sugar outfit	0·66	5·99	128	9
Sugaring arch	0·79	6·30	50	1

These results would show that in the country method of boiling the use of 4 pans is much more economical of fuel than the use of 2 pans, requiring only about 75 per cent. of the fuel required by the latter to make the same quantity of *gur*. When only 1 pan is used per furnace there is a still greater wastage of fuel.

The iron pan used on a furnace fitted with fire bars has given results far superior to any other methods of boiling, being distinctly an improvement on the maple sugar outfit.

As regards the juice dealt with in a given time, that is, the rapidity of concentration, in the case of the country system the amount seems almost directly proportioned to the number of pans in use. Thus with 1, 2, and 4 pans the number of lb. of juice dealt with per hour was 20, 40, and 83 respectively. The Chinsurah pan dealt with 102 lb. per hour on an average.

Recommendations.

1. It seems that it is possible to exercise a considerable economy of fuel in the native production of palm *gur*. Further work should therefore be carried out with the object of evolving the most suitable type of furnace.

2. For the present the indications are that the introduction of shallow iron pans in combination with a furnace fitted with iron bars would cause considerable economy in fuel consumption.

3. In some of our experiments, notably with the maple sugar plant and occasionally with the iron pan, we have been able to make a maund of *gur* with the consumption of only about 2 maunds of coal. This means that 1 maund of coal is about equivalent as fuel to $2\frac{1}{2}$ maunds of wood.

If a good furnace could be designed to burn coal there are many places where it would pay to use coal as fuel instead of wood, since coal could be obtained in many of the sugar districts at 6 annas* per maund of 82 lb.

4. Where fuel is getting scarce it might be worth while planting *Casuarina* trees in groves in certain areas as is done in certain parts of Madras. These trees are quick growers and do very well in Bengal.

* Pre-war rate.

PART IV. CONCLUSIONS.

1. The experiments show that the practice of liming the collecting pots before collection of juice should be introduced into the palm sugar districts of Bengal. The benefits which would be derived from this practice are :—

(*a*) The *gur* made would be of a much better quality from the refining point of view, because the lime destroys living organisms in the juice and also prevents the action of the enzyme invertase which converts the cane sugar into glucose and fructose.

(*b*) The yield of *gur* would be increased to some extent, for, owing to the reason set out under (*a*), fermentation of the sugar would be checked.

(*c*) The juice flowing in the day time could be collected and used for *gur* production. At present it is only rarely collected and even then only made into a sticky, non-crystalline treacle. It has been shown by actual measurements that if this day juice were used for *gur*-making it would mean an increase in yield of *gur* of something like 20 per cent.

2. The dark colour of date palm *gur* is due to the presence of alkaline constituents in the juice. By neutralizing this acidity with any acid substance just before boiling a perfectly light-coloured *gur* may be obtained. Apart from the common mineral acids tamarind fruit extract or alum may be used for this purpose.

3. The present furnaces in use for the manufacture of *gur* are very wasteful of fuel and there is room for work in designing more economical furnaces.

4. The native palm sugar refining industry is still of very large dimensions in Bengal. It is very wasteful and slow. It would seem well worth giving a good trial to centrifugals for doing this work. We made quite a good quality of sugar by the use of centrifugals.

5. Our further work on this industry only confirms our previous opinion that a thorough trial should be given to a scheme for producing white sugar or a good grade of raw sugar directly from the juice on the factory scale. We are convinced that the wild date palm is a very cheap source of sugar.

PUBLICATIONS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE IN INDIA.

TO BE HAD FROM

THE OFFICE OF THE AGRICULTURAL ADVISER TO THE GOVERNMENT OF INDIA, PUSA, BIHAR,
and from the following Agents :—

(1) THACKER, SPINK & CO., CALCUTTA.
(2) W. NEWMAN & CO., CALCUTTA.
(3) RAI M. C. SIRCAR BAHADUR & SONS, CALCUTTA.
(4) HIGGINBOTHAMS, LTD., MADRAS.
(5) THOMPSON & CO., MADRAS.
(6) D. B. TARAPOREVALA, SONS & CO., BOMBAY.
(7) THACKER & CO., LTD., BOMBAY.
(8) SUNDER PANDURANG, BOMBAY.
(9) RAI SAHIB M. GULAB SINGH & SONS, LAHORE.
(10) MANAGER, EDUCATIONAL BOOK DEPÔT, NAGPUR.

A complete list of the publications of the Imperial Department of Agriculture in India can be obtained on application from the Agricultural Adviser to the Government of India, Pusa, Bihar, or from any of the above-mentioned Agents.

These publications are :—

1. The *Agricultural Journal of India*. A Quarterly Journal dealing with subjects connected with agricultural economics, field and garden crops, economic plants and fruits, soils, manures, methods of cultivation, irrigation, climatic conditions, insect pests, fungus diseases, co-operative credit, agricultural cattle, farm implements, and other agricultural matters in India. Illustrations, including coloured plates, form a prominent feature of the Journal. It is edited by the Agricultural Adviser to the Government of India. *Annual Subscription*, Rs. 6 or 8*s*. 6*d*., including postage. Single copy, Rs. 2 or 3*s*.

2. Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Imperial Cotton Specialist).

3. Annual Report on the Progress of Agriculture in India.

4. Proceedings of the Board of Agriculture in India.

5. Proceedings of Sectional Meetings of the Board of Agriculture.

6. Memoirs of the Imperial Department of Agriculture in India.
   - (a) Botanical Series.
   - (b) Chemical Series.
   - (c) Entomological Series.
   - (d) Bacteriological Series.
   - (e) Veterinary Series.

7. Bulletins issued by the Agricultural Research Institute, Pusa.

8. Books.

The following are the publications of the last two years :—

Report of the Agricultural Research Institute and College, Pusa (including the Report of the Imperial Cotton Specialist), for the year 1915-16. Price, As. 6 or 7*d*.

Scientific Reports of the Agricultural Research Institute, Pusa (including the Report of the Imperial Cotton Specialist), for the year 1916-17. Price, As. 9 or 10*d*.

AGRICULTURAL PUBLICATIONS.—(*Contd.*)

Report on the Progress of Agriculture in India for the year 1915-16. Price, As. 10 or 1*s.*

Report on the Progress of Agriculture in India for the year 1916-17. Price, As. 12 or 1*s.* 1*d.*

Proceedings of the Board of Agriculture in India, held at Pusa on the 7th February, 1916, and following days (with Appendices). Price, R. 1-2 or 1*s.* 9*d.*

Proceedings of the Board of Agriculture in India, held at Poona on the 10th December, 1917, and following days (with Appendices). Price, As. 13 or 1*s.* 3*d.*

Proceedings of the Mycological Conference, held at Pusa on the 5th February, 1917, and following days. Price, As. 2 or 3*d.*

MEMOIRS OF THE DEPARTMENT OF AGRICULTURE IN INDIA.

BOTANICAL SERIES.

Vol. VIII, No. I. The Wheats of Baluchistan, Khorasan, and the Kurram Valley, by GABRIELLE L. C. HOWARD, M.A. Price, R. 1-12 or 2*s.* 6*d.*

Vol. VIII, No. II. Observations on the Inheritance of Anthocyan Pigment in Paddy Varieties, by G. P. HECTOR, M.A., B.SC. Price, R. 1 or 1*s.* 6*d.*

Vol. VIII, No. III. Studies in Indian Sugarcanes, No. 2. Sugarcane Seedlings, including some Correlations between Morphological Characters and Sucrose in the Juice, by C. A. BARBER, SC.D. Price, Rs. 3 or 4*s.* 3*d.*

Vol. VIII, No. IV. Pollination and Cross-fertilization in the *Juar* Plant, by R. J. D. GRAHAM, M.A., B.SC. Price, R. 1 or 1*s.* 6*d.*

Vol. VIII, No. V. *Phytophthora* sp. on *Hevea brasiliensis*, by J. F. DASTUR, B.SC. Price, As. 12 or 1*s.*

Vol. VIII, No. VI. *Phytophthora* on *Vinca rosea*, by J. F. DASTUR, B.SC. Price, As. 8 or 9*d.*

Vol. IX, No. I. The Dissemination of Parasitic Fungi and International Legislation, by E. J. BUTLER, M.B., F.L.S. Price, R. 1-4 or 2*s.*

Vol. IX, No. II. The Inheritance of Characters in Rice, 1, by F. R. PARNELL, B.A. ; G. N. RANGASWAMI AYYANGAR, B.A. ; and K. RAMIAH, L.Ag. Price, R. 1-8 or 2*s.*

Vol. IX, No. III. *Orobanche* as a Parasite in Bihar, by F. J. F. SHAW, D.SC., A.R.C.S., F.L.S. Price, R. 1 or 1*s.* 6*d.*

Vol. IX, No. IV. Studies in Indian Sugarcanes, No. 3. The Classification of Indian Canes with special reference to the Saretha and Sunnabile Groups, by C. A. BARBER, SC.D. Price, Rs. 2-4 or 3*s.*

Vol. IX, No. V. *Phytophthora Meadii* n. sp. on *Hevea brasiliensis*, by W. MCRAE, M.A., B.SC., F.L.S. *(In the Press.)*

CHEMICAL SERIES.

Vol. IV, No. IV. The Gases of Swamp Rice Soils, Part III. A Hydrogen-Oxidizing Bacterium from these Soils, by W. H. HARRISON, D.SC.; and P. A. SUBRAMANIA AIYER, B.A. Price, As. 12 or 1*s.*

Vol. IV, No. V. Some Factors affecting the Cooking of Dholl (*Cajanus indicus*), by B. VISWANATH ; T. LAKSHMANA ROW, B.A.; and P. A. RAGHUNATHSWAMI AYYANGAR, D.A. Price, R. 1 or 1*s.* 6*d.*

Vol. IV, No. VI. The Insects attacking Stored Wheat in the Punjab and the Methods of combating them (including a Chapter on the Chemistry of Respiration), by J. H. BARNES, B.SC., F.I.C., F.C.S.; and A. J. GROVE, M.SC. Price, Rs. 3-8 or 5*s.* 6*d.*

Vol. IV, No. VII. Studies in the Chemistry and Physiology of the Leaves of the Betel-Vine (*Piper betle*) and of the Commercial Bleaching of Betel-Vine Leaves, Part II, by HAROLD H. MANN, D.SC.; and V. G. PATWARDHAN, B.Ag. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. I. The Gases of Swamp Rice Soils, Part IV. The Source of the Gaseous Soil Nitrogen, by W. H. HARRISON, D.SC.; and P. A. SUBRAMANIA AIYER, B.A. Price, Rs. 2 or 3*s.* 6*d.*

Vol. V, No. II. "Heart Damage" in Baled Jute, by R. S. FINLOW, B.SC., F.I.C., F.C.S. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. III. Experiments on the Improvement of the Date Palm Sugar Industry in Bengal, by HAROLD E. ANNETT, B.SC., F.I.C. ; GOSTA BEHARI PAL, M.SC., and INDU BHUSHAN CHATTERJEE, L.Ag. Price, R. 1 or 1*s.* 6*d.*

ENTOMOLOGICAL SERIES.

Vol. V, No. II. Indian Sugarcane Leaf-hopper (*Pyrilla aberrans*, Kirby), by C. S. MISRA, B.A. Price, Rs. 2 or 3*s.*

Vol. V, No. III. Report on a Collection of Termites from India, by KARIN and NILS HOLMGREN, Högskolas Zootomiska Institut, Stockholm, translated by T. BAINBRIGGE FLETCHER, R.N., F.L.S., F.E.S., F.Z.S. Price, R. 1 or 1*s.* 6*d.*

Vol. V, No. IV. On a Collection of Sphecoidea sent by the Agricultural Research Institute, Pusa, Bihar, by ROWLAND E. TURNER, F.Z.S., F.E.S. Price, As. 12 or 1*s.*

BACTERIOLOGICAL SERIES.

Vol. I, No VII. A Bacterial Disease of Wheat in the Punjab, by C. M. HUTCHINSON, B.A. Price, As. 12 or 1*s.*

VETERINARY SERIES.

Vol. II, No. VIII. *Kumri*: Combined Diffuse Sclerosis and Central Poliomyelitis of Horses, by G. H. K. MACALISTER, M.A., M.D., D.P.H. Price, R. 1-8 or 2*s.* 6*d.*

Vol. III, No. I. The Vitality of the Rinderpest Virus outside the Animal Body under Natural Conditions, by A. W. SHILSTON, M.R.C.V.S. Price, As. 12 or 1*s.*

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA.

No. 58. *Calocoris angustatus*, Leth., by E. BALLARD, B.A., F.E.S. Price, As. 4 or 5*d.*

No. 59. One Hundred Notes on Indian Insects, by T. BAINBRIGGE FLETCHER, F.L.S., F.E.S., F.Z.S. Price, As. 8 or 9*d.* (*Out of print.*)

No. 60. A Comparison of the "Defibrination" and "Oxalate" methods of Serum Preparation as applied to Hæmorrhagic Septicæmia and Anthrax Sera, together with some Analyses of Buffalo and Hill Bull Blood, by R. V. NORRIS, M.Sc., D.Sc. Price, As. 3 or 4*d.*

No. 61. Soil Aeration in Agriculture, by ALBERT HOWARD, C.I.E., M.A. Price, As. 4 or 5*d.*

No. 62. A Preliminary Chemical Study of the Rices of Bihar and Orissa, by JATINDRA NATH SEN, M.A., F.C.S. Price, As. 4 or 5*d.*

No. 63. A Modified Method of Green-Manuring, by C. M. HUTCHINSON, B.A. Price, As. 2 or 3*d.*

No. 64. Rinderpest—Preparation of Anti-serum, by A. W. SHILSTON, M.R.C.V.S. Price, As. 3 or 4*d.*

No. 65. A Study in the Assimilation of Nutrients by the Rice Plant, by JATINDRA NATH SEN, M.A., F.C.S. Price, As. 2 or 3*d.*

No. 66. Berseem as a new fodder crop for India, by G. S. HENDERSON, N.D.A., N.D.D. (Second Edition). Price, As. 2 or 3*d.*

No. 67. Third Report on the Improvement of Indigo in Bihar, by A. HOWARD, C.I.E., M.A.; and GABRIELLE L. C. HOWARD, M.A. Price, As. 4 or 5*d.*

No. 68. Saltpetre—Its Origin and Extraction in India, by C. M. HUTCHINSON, B.A. Price, As. 4 or 5*d.*

No. 69. Sugar and the Sugarcane in the Gurdaspur District, by J. H. BARNES, B.Sc., F.I.C., F.C.S. Price, As. 14 or 1*s.* 3*d.*

No. 70. The Composition of some Indian Feeding Stuffs, by J. N. Sen, M.A., F.C.S. Price, As. 10 or 1*s.*

No. 71. Water Hyacinth (*Eichornia crassipes*): Its value as a Fertilizer, by R. S. FINLOW, B.Sc., F.I.C.; and K. MCLEAN, B.Sc. Price, As. 5 or 6*d.* (*Out of print.*)

BULLETINS ISSUED BY THE AGRICULTURAL RESEARCH INSTITUTE, PUSA.—(*Concld.*)

No. 72. A Note on Jhooling in Camels, by H. E. CROSS, M.R.C.V.S., D.V.H., A.SC. Price, As. 2 or 3*d.*

No. 73. New Agricultural Implements for India, by G. S. HENDERSON, N.D.A., N.D.D. (Second Edition). Price, As. 2 or 3*d.*

No. 74. Second Report on the Experiments carried out at Pusa to improve the Mulberry Silk Industry, compiled under the direction of the Imperial Entomologist, by M. N. DE. Price, As. 4 or 5*d.*

No. 75. The Pebrine Disease of Silkworms in India, by C. M. HUTCHINSON, B.A. Price, As. 3 or 4*d.*

No. 76. Experiments with Emulsions for Protecting Camels against the Attacks of Blood-sucking Flies, by H. E. CROSS, M.R.C.V.S., D.V.H., A.SC. Price, As. 2 or 3*d.*

No. 77. Some Camel-feeding Experiments, by H. E. CROSS, M.R.C.V.S., D.V.H., A.SC. Price, As. 2 or 3*d.*

No. 78. Smuts of Jowar (*Sorghum*) in the Bombay Presidency, by G. S. KULKARNI, L.AG. Price, As. 4 or 5*d.*

No. 79. Prussic Acid in Burma Beans, by F. J. WARTH, B.SC., M.SC.; and KO KO GYI. Price, As. 2 or 3*d.*

No. 80. Are Camels Susceptible to Black Quarter, Rinderpest and Hæmorrhagic Septicæmia, by H. E. CROSS, M.R.C.V.S., D.V.H., A.SC. (*In the press.*)

No. 81. The Value of the Phosphatic Manures in India and the Possibility of their Manufacture on a Larger Scale. Being evidence submitted to the Committee appointed to discuss this question (Subject IX) at the meeting of the Board of Agriculture, Poona, 1917. Edited, with an Introduction, by W. A. DAVIS, Chairman of the Committee. Price, As. 4 or 5*d.*

No. 82. The Improvement of the Indigenous Methods of *Gur* and Sugar making in the United Provinces, by WILLIAM HULME, and R. P. SANGHI. (*In the press.*)

Indigo Publication No. 1. A Study of the Indigo Soils of Bihar. The urgent necessity of immediate phosphate manuring if crops are to be maintained, by W. A. DAVIS, B.SC., A.G.G.I. Price, R. 1-4 or 2*s.*

Indigo Publication No. 2. Present Position and Future Prospects of the Natural Indigo Industry, by W. A. DAVIS, B.S.C., A.C.G.I. Price, As. 10 or 1*s.*

Indigo Publication No. 3. The Loss of Indigo caused by Bad Settling and the means of obviating this: The use of Dhak Gum: its effect on yield and quality, by W. A. DAVIS, B.SC., A.C.G.I. Price, As. 4 or 5*d.*

BOOKS.

"Indian Insect Pests," by H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S. Price, R. 1-8 or 2*s.* (*Out of print.*)

"Indian Insect Life," by H. MAXWELL-LEFROY, M.A., F.E.S., F.Z.S.; and F. M. HOWLETT, B.A. 786 pp. Price, Rs. 20 or 30*s.* (*Out of print.*)

"Wheat in India," by ALBERT HOWARD, M.A., A.R.C.S., F.L.S.; and GABRIELLE L. C. HOWARD, M.A. 288 pp. Price, Rs. 5 or 7*s.* 6*d.*

"A Description of the Imperial Bacteriological Laboratory, Muktesar: Its Work and Products," by Major J. D. E. HOLMES, M.A., D.SC., M.R.C.V.S. Price, As. 8 or 9*d.*

"Agriculture in India," by JAMES MACKENNA, M.A., I.C.S. Price, As. 4 or 5*d.*

"Some Diseases of Cattle in India. A handbook for stock-owners." Price, As. 8 or 9*d.*

"The Importance of Bacterial Action in Indigo Manufacture," by C. M. HUTCHINSON, B.A. Price, As. 2 or 3*d.*

"Report of the Proceedings of the Second Entomological Meeting, held at Pusa on the 5th—12th February, 1917." Price, Rs. 3.